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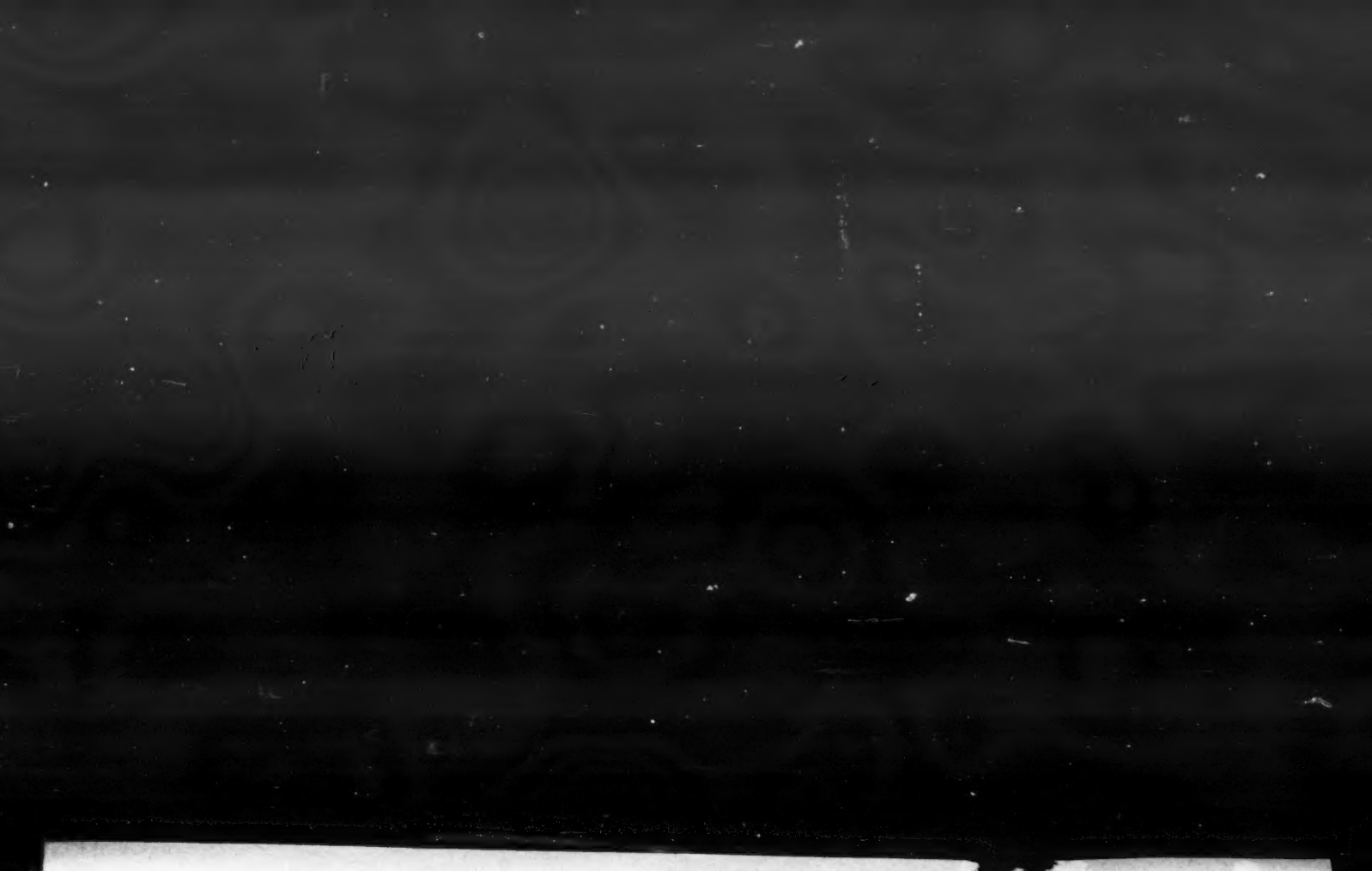

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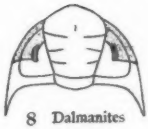

8 Dalmanites

HYPOPARIA

9 Agnostus

10 Microdiscus

11 Harpes

12 Trinucleus

13 Ampyx

OPISTHOPARIA

14 Atops

15 Conocoryphe

16 Ptychoparia

17 Olenus

18 Asaphus

19 Illænus

20 Proëtus

21 Bronteus

22 Lichas

23 Acidaspis

PROPARIA

24 Placoparia

25 Encrinurus

26 Calymene

27 Dipleura

28 Cheirurus

29 Dalmanites

30 Dalmanites

31 Chasmops

32 Acaste

33 Phacops

CLASSIFICATION OF TRILOBITES. Beecher.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. VIII. — *Outline of a Natural Classification of the Trilobites;* by CHARLES E. BEECHER. (With Plate III.)

Introduction.

WITH the possible exception of the barnacles, no group of arthropods has received more varied treatment by specialists than the trilobites. This taxonomic uncertainty has been due mainly to a lack of knowledge of the structure, and to certain real or fancied resemblances to *Limulus.*

The early references of trilobites to the mollusks, insects, and fishes need not be noticed, for since they have been made the subject of special study, they have been commonly classed with the crustacea, and placed near the phyllopods by most observers. Quite a number of naturalists, however, still divorce the trilobites and limuloids from the crustacea and ally them with the arachnids. It is not proposed at this time to discuss the homologies of *Limulus*, but the trilobites show the clearest evidence of primitive crustacean affinities, in their protonauplius larval form, their hypostoma and metastoma, the five pairs of cephalic appendages, the slender jointed antennules, the biramous character of all the other limbs and their original phyllopodiform structure. They differ from *Limulus*, not only in most of these regards, but also in not having an operculum. From this and all other arthropods, they are distinguished by having compound eyes on free cheek pieces which apparently represent the pleura of a head segment that is otherwise lost, except possibly in some forms of stalked eyes and in the cephalic neuromeres of later forms. The most recent discussions as to the affinities of trilobites are to be found in the papers by Bernard,[7, 8, 9, 10] Kingsley,[23] Woodward,[24] and the

writer,[5] where from the facts presented, their intimate relationships with the crustacea follow as a necessary corollary.

Previous Classifications.

The various schemes of classification that have been applied to the trilobites since that of Brongniart,[11] in 1822, have been enlarged and revised by various authors, until, at the present time, no particular arrangement of the families or genera can be said to be endorsed. The one which is generally recognized as manifestly faulty, that of Barrande,[3] is the one most commonly found in text-books and special memoirs. Barrande's definitions and limitations of the generic and family groups were natural and accurate, showing a most complete knowledge of generic and specific values, but in the grouping and arrangement of the families, he selected characters of secondary rank.

Of all the investigators who have attempted any classification of the families, J. W. Salter[32] seems to have had the clearest insight into the important value of certain characters, and to have approached nearest to a natural system. In zoölogical research, the study of ontogeny and the principles of morphogenesis were then scarcely recognized as having any direct application. It is quite remarkable, therefore, that Salter, as early as 1864, should have singled out, as the basis of his subdivisions, the characters which are the dominant variants in ontogeny.

It is not necessary in this place to discuss all the classifications which have been proposed. Barrande[3] gives a complete resumé down to 1850, and shows in a very satisfactory manner the weak points of each, furnishing strong reasons as to why they are unnatural and therefore untenable. The underlying principles of these early attempts at a classification are here briefly summarized. (1) The first classification of trilobites was advanced by Brongniart[11] in 1822, in which all the forms previously known as *Entomolithus paradoxus* were shown to belong to five distinct genera. (2) Dalman,[16] in 1826, made two groups based upon the presence or absence of eyes. (3) Quenstedt,[30] in 1837, recognized the number of thoracic segments and the structure of the eyes as of the greatest importance. (4) Milne-Edwards,[28] in 1840, considered the power of enrollment as of prime value. (5) Goldfuss,[20] in 1843, made three groups, depending on the presence or absence of eyes and their structure. (6) Burmeister,[12] in 1843, accepted the two divisions of Milne-Edwards, and laid stress on the nature of the pleura and the size of the pygidium. (7) Emmrich's first scheme,[17] in 1839, was founded on the shape of the pleura, the presence or absence of eyes and their structure. (8) The later classification of the same author,[18] published in 1844, was

based on whether the abdomen was composed of fused or free segments, and the minor divisions depended chiefly on the structure of the eyes and the facial suture. (9) Corda,[34] in 1847, placed all trilobites in two groups, one having an entire pygidial margin, and the other with the pygidium lobed or denticulate. (10) McCoy,[35] in 1849, took the presence or absence of a facet on the pleura for a divisional character. As this is an indication of the power or the inability of enrollment, it does not differ materially from the schemes of Milne-Edwards and Burmeister.

Zittel,[36] in a historial review brought down to 1885, includes in addition the schemes of Barrande and Salter, and remarks that the basis of Barrande's general grouping, namely, the structure of the pleura, has neither a high physiological nor morphological meaning. Both Barrande and Salter recognize nearly the same families, with slight differences, and the latter adopts a division into two lines, based on the number of body rings and the size of the pygidium. These include and are themselves included in four groups, founded on the presence and form of the facial suture and the structure of the eyes.

Haeckel* has recently given the trilobites their full value in a classification of the articulates. Although he has not advanced a detailed classification, still it is desirable to review the ordinal groups which he proposes. He considers the *Trilobita* as a legion under the first class, *Aspidonia*, of the crustacea, which is characterized as being without a nauplius larval form and as having a pair of preoral antennæ. In this class is also included the legion *Merostomata*, the *Trilobita* being especially distinguished by the number and character of the legs. The writer[5] believes that it is now satisfactorily demonstrated that the protaspis, or early larval form of the trilobite, is a protonauplius, and homologous with the nauplius of higher crustacea. Therefore, the *Trilobita* cannot remain in the *Aspidonia* as here defined.

Haeckel further divides the *Trilobita* into two orders, the first, the *Archiaspides* (or *Protrilobita*), and the second, the *Eutrilobita* (or *Pygidiata*). The *Archiaspides* is represented by the families Olenida and Triarthrida, and is distinguished by the absence of a real pygidium, and by the complete homonomy of the numerous body segments and their phyllopodiform appendages. The families are themselves distinguished by the semicircular or crescent-shaped cephalon and by the presence or absence of genal spines. The *Eutrilobita* is represented by the families Asaphida and Calymenida, and is marked by the heteronomy of the body segments as expressed in the functional pygidium.

* Systematische Phylogenie der wirbellosen Thiere (Invertebrata). Zweiter Theil. 1896.

Salter, Burmeister, and Emmrich have, as previously noticed, attempted to use the comparative size and development of the pygidium for dividing the trilobites into groups larger than families, and it seems evident from the present state of knowledge that it is impossible to make this character of more than family or even generic value. Many of the genera which must naturally be included in the *Archiaspida* have pygidia that cannot be said to be rudimentary, obsolete, or wanting in function. Even those genera having pygidia with few segments, as *Mesonacis*, *Holmia*, *Paradoxides*, *Selenopeltis*, *Dicranurus*, *Bronteus*, *Harpes*, etc., show in many other more important characters that they are highly differentiated and specialized forms and that this feature is one expression of such development. The futility of the scheme is at once evident when a comparison is made between allied genera which present marked differences in the size and segmentation of the pygidium, as *Phacops* and *Dalmanites*, *Ceraurus* and *Encrinurus*, *Calymene* and *Homolanotus*, *Harpes* and *Trinucleus*, *Mesonacis* and *Zecanthoides*, *Paradoxides* and *Dikelocephalus*.

The last classification to be noticed is that of E. J. Chapman,[12] in 1889, in which four suborders or primary groups are proposed, differing considerably from any previous arrangement, and based upon arbitrary features of general structure and configuration, especially the form of the glabella, whether wide, conical, or enlarged. Twenty-seven families are recognized. In this scheme, *Trinucleus*, *Ampyx*, and *Æglina* form one section; *Paradoxides* and *Acidaspis*, together with *Phacops* and *Encrinurus*, another; all under one suborder. Omitting the Agnostidæ, there are here considered in a single suborder the most characteristic representatives of nearly all the types of trilobite structure. *Proëtus*, *Cyphaspis*, and *Arethusina* fall into three sections, under two suborders, although these genera, on account of their great similarity in essential points, are placed in a single family by most authors. A further analysis of this classification in its broader lines would be unprofitable. It is sufficient to state that the facts obtained from the study of the ontogeny of any species are completely in discordance with these classifications, and clearly demand other interpretations.

Rank of the Trilobites.

As to the rank of the trilobites in a classification of the crustacea, there is also much diversity of opinion. They have long been regarded as an order, but any attempt to include them in this way under higher groups, such as the *Entomostraca*, *Malacostraca*, or *Palæocarida*, results in such broad generalities and looseness of definition as to render these divisions of little

value. Even the *Entomostraca*, as restricted to the orders Phyllopoda, Ostracoda, Copepoda, and Cirripedia, seems heterogeneous and probably polyphyletic. Milne-Edwards,[27] Gegenbaur,[19] Walcott,[28] and others have considered the trilobites as belonging to a class of arthropods intermediate between the crustacea and arachnids. Some recent authors, as Lang,[24] have attempted to overcome the difficulty by attaching them as an appendage ("Anhang") to the crustacea. Kingsley,[23] on the other hand, has placed them as a subclass of the crustacea, leaving all the other crustacea to come under a second subclass, the *Eucrustacea*. The present state of knowledge of their structure and development is in favor of giving the trilobites the rank of a subclass, but for purposes of comparison and correlation, the fullest results can be brought out by recognizing the old and well-known subclasses,—the *Entomostraca* and *Malacostraca*.

The following tabular view of the leading points of the comparative morphology of the three subclasses is introduced to show, first, the claims of the *Trilobita* as an equivalent group, and, second, the progressive differentiation of characters. In nearly every particular the trilobite is very primitive, and closely agrees with the theoretical crustacean ancestor. Its affinities are with both the other subclasses, especially their lower orders, but its position is not intermediate.

Comparative Morphology of Crustacea.

Subclass I. *Trilobita.*	Subclass II. *Entomostraca.*	Subclass III. *Malacostraca.*
1. All marine.	Marine and fresh water.	Marine and fresh water.
2. Free.	Free, parasitic, and attached.	Free and parasitic.
3. Body longitudinally triregional.	Various.	Various.
4. Larva a protonauplius.	Larva almost universally a nauplius.	Larva generally a zoea, a nauplius stage being often developed before hatching, except in *Euphausia* and *Peneus*.
5. Number of segments variable.	Number of segments variable.	Definite number of segments.
6. Cranidium of five fused segments.	Head of five fused segments to which, rarely, a thoracic segment is added.	Head of five fused segments to which one or more, or all of the thoracic segments may unite, forming a more or less complete cephalothorax.
7. Ocelli rarely present.	Ocelli present throughout life.	Ocelli absent in adult forms.
8. Paired compound sessile eyes on cheek pieces usually present.	Paired compound eyes usually present; stalked or sessile. Absent in adult Cirripedia and some Copepoda.	Paired compound eyes usually present; stalked or sessile.

Subclass I. *Trilobita.*	Subclass II. *Entomostraca.*	Subclass III. *Malacostraca.*
9. Thorax distinct; number of segments variable, all free.	Thorax with variable number of segments.	Thorax with eight segments, some of which are generally united with the head.
10. Abdomen distinct; variable number of fused segments.	Abdomen with variable number of separate segments.	Abdomen of seven generally free segments; eight in Leptostraca.
11. All segments of cranidium, thorax, and abdomen, except the anal segment, carry paired appendages	Some segments without appendages.	All segments usually carry appendages except the last one or two.
12. All appendages biramous except antennules	Some appendages are modified and have lost biramous structure.	Some appendages have lost biramous structure.
13. Appendages typically phyllopodiform. Exopodite a swimming leg; endopodite modified into a crawling leg.	Appendages generally greatly changed in most orders; phyllopodiform in young forms and throughout life in Phyllopoda.	Appendages typically phyllopodiform, but greatly modified in all but the lowest order (*Nebalia*).
14. All appendages of the head except antennules pediform.	Some appendages of the head modified into rowing organs, mandibles, or suckers.	Some appendages of the head modified into mandibles, or organs for seizing food.
15. Thoracic appendages ambulatory and swimming.	Thoracic appendages ambulatory, swimming, and seizing.	Thoracic appendages ambulatory, swimming, and seizing.
16. Abdominal limbs on all segments except the anal, phyllopodiform.	Abdominal limbs generally wanting.	Abdominal limbs often reduced except the last pair, which with telson frequently form a caudal fin. Chiefly branchial in some groups.
17. Coxal elements of all limbs forming gnathobases, which become manducatory organs on the head.	Coxal elements seldom forming gnathobases except on the head.	Coxal elements seldom forming gnathobases except on the head; never on the abdomen.
18. Respiration cuticular and by fringes on exopodites.	Respiration mainly cuticular and by the limbs and gill appendages.	Respiration cuticular and by the limbs and epipodites.

The more primitive characters of the trilobites as drawn from the foregoing table may be summarized as follows: (1) They are all free marine animals; (2) the animal has a definite configuration; (3) the larva is a protonauplius-like form; (4) the body and abdomen are richly segmented, and the number of segments is variable; (5) the head corresponds to the typical crustacean; (6) the thorax and abdomen are always distinct, the number of segments in each being variable; (7) all segments except the anal bear paired appendages; (8) all appendages are typically phyllopodiform; and (10) the coxal elements of all limbs form gnathobases, which become organs of manducation on the head.

It may be questioned by some whether the present state of knowledge of the ventral structure of trilobites warrants such general assertions as to details of organization. In the first place, it must be granted that there is a remarkable uniformity in the features of the dorsal crust, which naturally reflects to a degree the differentiation and variation of the organs and appendages of the ventral side. Furthermore, the actual appendages have been observed in such diverse and characteristic genera as *Trinucleus*, *Triarthrus*, *Asaphus*, *Ceraurus*, and *Calymene*, and found to conform closely to a single type, so that it seems safe to assume a like agreement throughout.

Morphology of the Cephalon.

The structure of the trilobite head suggests homologies which should be noticed here, and if these correlations are based upon true structural likenesses, they serve not only to emphasize the primitive character of the trilobite, but also aid in interpreting certain organs and structures in the higher crustacea.

The five fused somites of the crustacean head are generally believed to correspond to the third, fourth, fifth, sixth, and seventh neuromeres, leaving the first and second unrepresented either by distinct segments or appendages. These two neuromeres commonly constitute most of the cerebral mass above the œsophagus, and enervate the ocelli and paired eyes. In some, the antennæ are enervated from supra-œsophageal ganglia, while in other forms their ganglia are infra-œsophageal. It was formerly supposed that the stalked eyes of the higher crustacea represented appendages of a head segment, but this belief has been abandoned on account of the derivation of stalked out of sessile organs, as in *Peneus*, and also because the eyes do not always have a relatively fixed position, but may pertain to the first, second, or third head segments. Their structural position in the trilobites, however, is invariable, and it seems probable that in some families of higher crustacea, the eyes are in exact correlation, and may be similarly interpreted.

The writer[5] has previously discussed this question, and adduced reasons for considering the free cheeks in trilobites as "the pleura of an oculiferous head segment." In many species (*Dalmanites*, *Æglina*, etc.), the free cheeks are continuous, forming one piece extending around the front of the head, between the cranidium and the hypostoma, while in others there is a separate piece, the epistoma, between the proximal ends of the cheek pieces holding a like position. These structures occupy the exact position of a true segment, and since, upon theoretical grounds, additional head segments

are to be accounted for, the only satisfactory correlation is to consider them as such. Furthermore, the free cheeks are distinctly separated from the cranidium by an open suture, and may be wholly converted into eyes, as in *Æglina armata* Barr., or the unfacetted portion may be reduced to almost nothing, as in *Deiphon*. In such cases, the parallelism is exact with true movable eyes. Bernard[7] concludes from his studies of *Apus* that the hypostoma is homologous with the annelid prostomium. This would make the hypostoma represent the first, and the free cheeks the second of the obsolete segments. Thus the trilobite cephalon would fulfil the demand for additional evidences of primitive head segments, and account for the development of eyes separate from the cephalothorax as commonly restricted.

Supposed evidences of free cheeks or of facial sutures have been recognized in *Limulus*, *Hemiaspis*, and *Bunodes*, but these seem really to correspond to the lines on the dorsal surface of the cephalon of *Harpes* and some *Trinucleus*, running from the glabella to the eye spots and to the margin, and are not the sutures marking the limits of the free cephalic elements, as in *Asaphus* and *Proëtus*. *Limulus*, however, has a suture comparable to that in *Harpes* and *Trinucleus*, extending around the ventral border of the cephalothorax nearly to the posterior angles, and partly separating the ventral plate. In the process of moulting, this suture opens and enables the animal to free itself from its former test.

These interpretations may be employed to some advantage in correlating the segmentation of the trilobite cephalon. As previously stated, the recognized plan in the nervous system of a generalized crustacean requires that there should be a brain or supra-œsophageal ganglion enervating (a) the unpaired eye, (b) the frontal sensory organs and stalked eyes, and (c) the anterior antennæ; then a ventral nervous chord consisting of a succession of double ganglia enervating, respectively, the second pair of antennæ, the mandibles, the first pair of maxillæ, the second pair of maxillæ, and lastly each of the paired thoracic and abdominal appendages. Altogether, there are seven neuromeres pertaining to the head, and on the basis that each neuromere corresponds to an original segment, as on the post-cephalic region, there would need to be this number accounted for. The anterior segment, or number one in the trilobites, would be represented by the hypostoma; the second segment, by the paired eyes, free cheeks, and epistoma; the third, by the anterior lobe of the glabella and the first antennæ; the fourth, by the second lobe of the glabella and the second pair of antennæ; the fifth, by the third lobe of the glabella and the mandibles; the sixth, by the fourth lobe of the glabella

and the first maxillæ; and the seventh, by the neck lobe, or occipital ring, and the second pair of maxillæ. The five annulations, or lobes, of the axis of the cranidium, since they primarily carry fulcra for the attachment of muscles supporting or moving the appendages, could thus be interpreted in terms of the ventral structure, making the first lobe the antennulary, the second the antennary, the third the mandibular, the fourth the first maxillary, and the fifth the second maxillary.

No other group of crustacea furnishes such constant and well-developed structures representing the second theoretical head segment, which is obscure or obsolete in all the living groups, excepting probably the stalked eyes of some crustacea and the movable ocular segment of the Stomatopods. For this reason, in addition to the many other important differences previously noted in the table of comparative morphology, the trilobites are regarded as a subclass, and the relative denomination and structural relations of this second segment, along with other characters, are considered as of sufficient physiological and morphological importance to determine the ordinal divisions.

Principles of a Natural Classification.

Most satisfactory and conclusive results have already come from the application of the law of morphogenesis, or the recapitulation theory, to various groups of animals, by means of which their natural classification and phylogenetic relations have been determined. Hyatt[21] says on this point (1889): "We have endeavored to demonstrate that a natural classification may be made by means of a system of analysis in which the individual is the unit of comparison, because its life in all its phases, morphological and physiological, healthy or pathological, embryo, larva, adolescent, and old (ontogeny), correlates with the morphological and physiological history of the group to which it belongs (phylogeny)." It is also interesting to note that Agassiz[1] recognized in ontogeny a standard of classification. One of his strongest statements is as follows: "Embryology [=ontogeny] will in the end furnish us with the means of recognizing the true affinities among all animals, and of ascertaining their relative standing and normal position in their respective classes with the utmost degree of accuracy and precision."

These principles can be best applied in a group of animals which has a geological history more or less complete, and which is not wholly parasitic or greatly degenerated. It is of the greatest importance, also, to study the ontogeny of primitive and non-specialized species, because without very complete paleontological evidence, the development of a much later

derived form may be so involved with larval adaptations and accelerated characters as to be misleading.

The trilobites lend themselves to this treatment in fulfilling most of the necessary conditions. They have a known geological history stretching through the entire paleozoic, from the beginning of the Cambrian to the Permian. Their structure is generalized and quite uniform, and no sessile, attached, parasitic, land or fresh water species are known. The ontogeny of all the principal groups has been studied, including Cambrian, Ordovician, Silurian, and Devonian types.

The trilobites necessarily furnish little information of the stages of growth which may be classed as embryonic. The early embryonic stages are not preserved as fossils, and therefore may be omitted. In this category are the *protembryo*, or the ovum in its unsegmented and segmented stages (the so-called "eggs of trilobites" may of course represent any stage of embryonic development before the escape of the young); the *mesembryo*, or blastosphere; the *metembryo*, or gastrula; the *neoembryo*, or planula-like stage; and the *typembryo*, when the first distinctive features make their appearance. The first embryonic stage recognized in the trilobites can be referred to the *phylembryo* as defined by Jackson,[22] when the animal may be clearly referred to its proper class. Since this period is distinctive for each class of animals and usually bears a separate name, it has been termed by the writer[5] the *protaspis* stage of trilobites. It closely approximates the protonauplius form, or the theoretical, primitive, ancestral larval form of the crustacea. Like the homologous nauplius of modern higher crustacea, it is the characteristic larval type common to the class. The nauplius is therefore considered as a derived larva modified by adaptation.

The post-embryonic stages of ontogeny have received the names *nepionic*, for the infantile or young; *neanic*, for the immature or adolescent; *ephebic*, for the mature or adult; and *gerontic*, for the senile or old. When especially applied to trilobites, the nepionic stages may include the animal when the cephalon and pygidium are distinct and the thorax incomplete. There would thus be as many nepionic stages as the number of thoracic segments. The neanic stages would be represented by the animal with all parts complete, but with the average growth incomplete. Final progressive growth and development of the individual would fall under the ephebic stage. Lastly, general evidences of senility would be interpreted as belonging to the gerontic stage.

Application of Principles for Ordinal Divisions.

In other classes of animals above the lower cœlenterates, the phylembryonic stage is the starting point from which correlations are made, and out of which all the higher groups are developed by a series of changes along certain lines. The protoconch represents this period in the cephalopods and gastropods; the prodissoconch, in the pelecypods; the protegulum, in the brachiopods, and the protechinus, in the echinoids. In the trilobites, the protaspis, as already stated, has the value of the phylembryo, and in its geological history and the metamorphoses it undergoes to produce the perfect trilobite, accurate information can be gained as to what the primitive characters are, and the relative values of other features acquired during the long existence of the class.

The simple characters possessed by the protaspis are the following, as drawn from the study of this stage in all the principal groups of trilobites: Dorsal shield minute, not more than ·4 to 1^{mm} in length; circular or ovate in form; axis distinct, more or less strongly annulated, limited by longitudinal grooves; head portion predominating; axis of cranidium with five annulations; abdominal portion usually less than one-third the length of the shield; axis with from one to several annulations; pleural portion smooth or grooved; eyes, when present, anterior, marginal, or submarginal; free cheeks, when visible, narrow and marginal. Examples, Plate III, figs. 1, 5.

During this stage, several moults took place before the complete separation of the pygidium or the introduction of thoracic segments. These brought about various changes, as the stronger annulation of the axis, the appearance of the free cheeks on the dorsal side, and the growth of the pygidium by the introduction of new appendages and segments, as indicated by the additional grooves on the axis and limb. A full representation of the variety and succession of these early protaspis stages is presented in the writer's paper on the "Larval Stages of Trilobites."[5] Some of the conclusions and discussions in that paper are made use of here.

In the earliest or Cambrian genera, the protaspis stage is by far the simplest expression of this period to be found. In the higher and later genera, the process of acceleration or earlier inheritance has pushed forward certain characters until they appear in the protaspis, thus making it more and more complex.

Taking the early protaspis stages in *Solenopleura*, *Liostracus*, or *Ptychoparia*, it is found that they agree exactly with the foregoing diagnosis in its most elementary sense. Since they are the characters shared in common by all the larvæ at this stage, they are taken as primitive and accorded that value

in dealing with adult forms possessing homologous features. Therefore, any trilobite with a large elongate cephalon, eyes rudimentary or absent, free cheeks ventral or marginal, and glabella long, cylindrical, and with five annulations, would naturally be placed near the beginning of any genetic series or as belonging to a very primitive stock.

Next must be considered the progressive addition of characters during the geological history of the protaspis, and in the ontogeny of the individual during its growth from the larval to the mature condition. It was shown in the paper already referred to, that there was an exact correlation to be made between the geological and zoölogical succession of first larval stages and adult forms, and therefore both may be reviewed together.

The first important structures not especially noticeable in all stages of the protaspis are the free cheeks, which usually manifest themselves in the meta- or para-protaspis stages, though sometimes even later. Since they bear the visual areas of the eyes, when they are present, their appearance on the dorsal shield is practically simultaneous with these organs, and before the eyes have travelled over the margin, the free cheeks must be wholly ventral in position. When first discernible, they are very narrow, and in *Ptychoparia* and *Sao* include the genal angles. In *Dalmanites* and *Cheirurus*, however, the genal angles are borne on the fixed cheeks. If, as Bernard[1] concludes, the crustacean head has been formed by the bending under, to the ventral side, of the anterior segments of an ancestral carnivorous annelid, this furnishes a means of further determining and also of satisfactorily correlating the prime significance and importance of the free cheeks.

Since the free cheeks are ventral in the earliest larval stages of all but the highest trilobites, and as this is an adult feature among a number of genera which on other grounds are very primitive, this is taken as generally indicative of a very low rank. It seems to mean that the second segment remains where it was mechanically placed, and retains its full somitic nature, though from the necessities of such a condition, true ventral segments must soon disappear through modification into other structures or through disuse as segments. The genera *Harpes*, *Agnostus*, *Trinucleus*, and their allies agree in having well-developed, continuous, ventral free cheeks, and constitute a natural group. As they possess one expression or type of the genesis of an important common character, based upon facts of development, it should stand as an ordinal character, and as such it is here taken. For this group, the name *Hypoparia* is proposed. It is fully defined, and its limitations established in the proper place in the classification.

The remaining genera of trilobites present two distinct types of head structure, dependent upon the extent and character of the free cheeks. In both, the free cheeks make up an essential part of the dorsal crust of the cephalon, being continued on the ventral side only as a doublure or infolding of the edge, similar to that of the free edge of the cranidium, the ends of the thoracic pleura, and the margin of the pygidium. They may be separated only by the cranidium, as in *Ptychoparia*, or by the cranidium and epistoma, as in *Illænus* and *Homalonotus*, or they may be united and continuous in front, as in *Æglina* and *Dalmanites*. One type of structure is distinguished by having the free cheeks include the genal angles, thus cutting off more or less of the pleura of the occipital segment. The genera belonging to this group constitute the second order, the *Opisthoparia*.

The third and last type of structure includes forms in which the pleura of the occipital segment extend the full width of the base of the cephalon, embracing the genal angles. The free cheeks are therefore separated from the cranidium by sutures cutting the lateral margins of the cephalon in front of the genal angles. Genera having this structure are here placed in the order *Proparia*.

Several genera, as *Calymene* and *Triarthrus*, have been described as having the facial sutures beginning at or cutting the apex of the genal angle, thus making it indeterminate whether they should be classed with the Opisthoparia or Proparia. It will be found, however, that some species of these genera leave no doubt as to the anterior or posterior position of the suture. The small genal spines of *Calymene callicephala* Green are situated on the ends of the fixed cheeks, while similar but larger spines in *Triarthrus spinosus* Billings are on the free cheeks, making the former belong to the Proparia and the latter to the Opisthoparia.

Application of Principles for Arrangement of Families and Genera.

The remaining characters to be noticed have chiefly family and generic values, and naturally follow the preceding discussions. They are of great assistance, both in determining the place of a family in an order, and the rank and genetic position of a genus in a family.

There is very satisfactory evidence that the eyes have migrated from the ventral side, first forward to the margin and then backward over the cephalon to their adult position. The most primitive larvæ should therefore present no evidence of eyes on the dorsal shield. Just such conditions are fulfilled

in the youngest larva of *Ptychoparia*, *Solenopleura*, and *Liostracus*. The eye line is present in the later larval and adolescent stages of these genera, and persists to the adult condition. In *Sao*, it has been pushed forward to the earliest protaspis, and is also found in the two known larval stages of *Triarthrus*. *Sao* retains the eye line throughout life, but in *Triarthrus* the adult has no traces of it. A study of the genera of trilobites shows that this is a very archaic feature, chiefly characteristic of Cambrian genera, and only appearing in the primitive genera of higher and later groups or as an evidence of degeneration. It first develops in the later larval stages of certain genera (*Ptychoparia*, etc.); next in the early larval stages (*Sao*); then disappears from the adult stages (*Triarthrus*); and finally is pushed out of the ontogeny (*Dalmanites*).

In *Ptychoparia*, *Solenopleura*, *Liostracus*, *Sao*, and *Triarthrus*, the eyes are first visible on the margin of the dorsal shield after the protaspis stages have been passed through, and later than the appearance of the eye lines; but in *Proëtus*, *Acidaspis*, *Arges*, and *Dalmanites*, through acceleration, they are present in all the protaspis stages, and persist to the mature or ephebic condition, moving in from the margin to near the sides of the glabella. Progression in these characters may be expressed, and in so far taken for general application among adult forms to indicate rank, as follows: (1) absence of eyes; (2) eye lines; (3) eye lines and marginal eyes; (4) marginal eyes; (5) submarginal eyes; (6) eyes near the pleura of the neck segment.

The changes in the glabella are equally important and interesting. Throughout the larval stages, the axis of the cranidium shows distinctly by the annulations that it is composed of five fused segments, indicating the presence of as many paired appendages on the ventral side. In its simplest and most primitive state, it expands in front, joining and forming the anterior margin of the head (larval *Ptychoparia* and *Sao*). During later growth, it becomes rounded in front, and terminates within the margin. In higher genera, through acceleration, it is rounded and well-defined in front, even in the earliest larval stages, and often ends within the margin (larval *Triarthrus* and *Acidaspis*). From these simple types of simple pentamerous glabellæ, all the diverse forms among species of various genera have been derived, through changes affecting any or all the lobes. The modifications usually consist in the progressive obsolescence of the anterior annulations, finally producing a smooth glabella, as in *Illænus* and *Niobe*. The neck segment is the most persistent of all, and is rarely obscured. The third, or mandibular, segment is frequently marked by two entirely separate lateral lobes, as in *Acidaspis*,

Conolichas, *Chasmops*, etc. Likewise, the fourth annulation carrying the first pair of maxillæ is often similarly modified in the same genera, also in all the Proëtidæ, and in *Cheirurus*, *Crotalocephalus*, *Sphærexochus*, *Ampyx*, *Harpes*, etc. Here again, among adult forms, the stages of progressive differentiation may be taken as indicating the relative rank of the genera.

The comparative areal growth of the free cheeks is expressed by the gradual moving of the facial suture toward the axis. As the free cheeks become larger, the fixed cheeks become smaller. In the most primitive protaspis stages, and in *Agnostus*, *Harpes*, and *Trinucleus*, the dorsal surface of the cephalon is wholly occupied by the axis and the fixed cheeks, while in the higher genera, the area of the fixed cheeks becomes reduced until, as in *Stygina* and *Phillipsia*, they form a mere border to the glabella. Therefore, the ratio between the fixed and free cheeks furnishes another means of assisting in the determination of rank.

The pleura from the segments of the glabella are occasionally visible, as in the young of *Olenellus*, but usually the pleura of the neck segments are the first and only ones to be distinguished on the cephalon, the others being so completely coalesced as to lose all traces of their individuality. The pleura of the pygidium appear soon after the earliest protaspis stage, and in some genera (*Sao*, *Dalmanites*) are even more strongly marked than in the adult state and much resemble separate segments. The growth of the pygidium is very considerable through the protaspis stage. At first, it is less than one-third the length of the dorsal shield, but by successive addition of segments, it soon becomes nearly one-half as long. In some genera, it is completed before the appearance of the free thoracic segments, all of which are added during the nepionic stages. An interpretation of these facts, to apply in valuing adult characters, would indicate that a very few segments, both in thorax and pygidium, may be evidence of arrested development or degeneration. On the other hand, the apparently unlimited multiplication of thoracic and especially of abdominal segments in some genera is also to be considered as a primitive character expressive of an annelidan style of growth. Genera like *Asaphus*, *Phacops*, etc., having a constant number of thoracic segments accompanied by other characters of a high order, undoubtedly represent the normal trilobite type.

These analyses and correlations clearly show that there are characters appearing in the adults of later and higher genera, which successively make their appearance in the protaspis stage, sometimes to the exclusion or modification of structures present in the most primitive larvæ. Thus, the larvæ of *Dal-*

manites or Proëtus, with their prominent eyes and glabella distinctly terminated and rounded in front, have characters which do not appear in the larval stages of ancient genera, but which may come in their adult stages. Evidently such modifications have been acquired by the action of the law of earlier inheritance, or tachygenesis.

In a classification of trilobites, for the purpose of illustrating the principles here enunciated, the ontogenies of *Sao* and *Dalmanites*, Plate III, figs. 1–8, are selected. *Sao* belongs to the ancient family Olenidæ of the order Opisthoparia, and naturally may be expected to furnish very clear evidence as to the relations of many lower and older genera. *Dalmanites*, also, with its simple head structure, will give similar data regarding the Proparia.

The early protaspis stage of *Sao*, Plate III, fig. 1, has no dorsal development of the free cheeks, and with the elongate form of the cephalic portion may be compared with the cephala of *Agnostus* and *Microdiscus*, and therefore correlates with the Hypoparia. The cephalon, at a later period of development, when the animal has two free thoracic segments, Plate III, fig, 2, shows the narrow marginal free cheeks and distinct eye lines. Here the resemblance to the cephala of *Atops* and *Conocoryphe*, Plate III, figs. 14, 15, is very marked, and indicates that the Conocoryphidæ is genetically the first family of the Opisthoparia. When *Sao* has eight thoracic segments, Plate III, fig. 3, the characters of the cephalon accord closely with *Ptychoparia* and *Olenus*, showing that these genera should precede it in arranging the genera of the family Olenidæ. Evidence is thus furnished for the proper position of the first two families of the order. Now, if the relative values of the differentiation of the glabella, the position of the eyes, and the size of the free cheeks are considered in the light of the preceding analyses of these features, the remaining families of the order, as represented in their typical genera, naturally arrange themselves as indicated in Plate III, figs. 18–23. There results (1) the Conocoryphidæ (represented by *Atops* and *Conocoryphe*, figs. 14, 15); (2) the Olenidæ (*Ptychoparia* and *Olenus*, figs. 16, 17); (3) the Asaphidæ (*Asaphus* and *Illænus*, figs. 18. 19); (4) the Proëtidæ (*Proëtus*, fig. 20); (5) the Bronteidæ (*Bronteus*, fig. 21); (6) the Lichadidæ (*Lichas*, fig. 22); and (7) the Acidaspidæ (*Acidaspis*, fig. 23).

For the Proparia, similar results are brought out by the study of the ontogeny of *Dalmanites*, and by comparisons with the characters governing the sequence of families in the Opisthoparia. The narrow marginal free cheeks place the Encrinuridæ and Calymenidæ as primitive. The small or obsolete eyes and the larval form of the glabella in the former

further show that this family should be placed at the beginning. The nepionic *Dalmanites*, with seven thoracic segments, has a head structure very similar to the adult *Cheirurus* (*Eccoptocheile*), fig. 28, thus making the Cheiruridæ precede the Phacopidæ. The arrangement of families under the Proparia accordingly will be (1) the Encrinuridæ (*Placoparia* and *Encrinurus*, Plate III, figs. 24, 25); (2) the Calymenidæ (*Calymene* and *Dipleura*, figs. 26, 27); (3) the Cheiruridæ (*Cheirurus* (*Eccoptocheile*), fig. 28); and (4) the Phacopidæ (*Dalmanites*, *Chasmops*, *Acaste*, *Phacops*, figs. 29–33).

The sequence of families in the most primitive order, Hypoparia, may now be easily disposed of. The genera are so aberrant and offer such conspicuous differences from ordinary trilobites, that it was considered better to delay their disposition until the variations in structure governing the arrangement of families in the higher orders were clearly shown. The degree of specialization of the glabella, of the form and character of the fixed cheeks, and the great range in the number of segments in the thorax and pygidium are strong evidence that we are dealing with the terminal genera of the order which must have attained its normal development in pre-Cambrian times. *Agnostus* and *Microdiscus* have so many protaspidian and larval characters that they must be considered more primitive than the other genera, although in some respects they show a high degree of specialization and even degeneration, as will be noticed under the family Agnostidæ. Moreover, *Harpes*, in its elongate cephalon, persistent ocelli, and many thoracic segments, is also quite primitive. *Trinucleus*, with ocelli only present in larval stages, a transverse cephalon, and genal spines belonging to the free cheeks, is considerably higher and properly comes last in the order, thus making the arrangement of families as follows: (1) Agnostidæ (*Agnostus*, *Microdiscus*, Plate III, figs. 9, 10); (2) Harpedidæ (*Harpes*, fig. 11); and (3) Trinucleidæ (*Trinucleus*, *Ampyx*, figs. 12, 13).

Diagnoses and Discussions.

Subclass Trilobita.

Marine crustacea, with a variable number of metameres; body covered with a hard dorsal shell or crust, longitudinally trilobate from the defined axis and pleura; head, thorax, and abdomen distinct. Head covered with a cephalic shield composed of a primitively pentamerous middle piece, the cranidium, and two side pieces, or free cheeks, which may be

separate or united in front, and carry the compound sessile eyes, when present; cephalic appendages pediform, consisting of five pairs of limbs, all biramous, and functioning as ambulatory and oral organs, except the simple antennules, which are purely sensory. Upper lip forming a well-developed hypostoma; under lip present. Somites of the thorax movable upon one another, varying in number from two to twenty-nine. Abdominal segments variable in number, and fused to form a caudal shield. All segments, thoracic and abdominal, carry a pair of jointed biramous limbs. All limbs have their coxal elements forming gnathobases, which become organs of manducation on the head. Respiration integumental and by branchial fringes on the exopodites. Development proceeding from a protonauplius form, by the progressive addition of segments at successive moults.

Heretofore it has been impossible to give an adequate diagnosis of the *Trilobita*, owing to the absence of information regarding certain important characters, and the obscurity of the information relating to some other features. It is believed that enough is now known to frame a definition of the class, which, in accuracy and completeness, will compare favorably with any based upon living groups. Such a definition brings out the fact that the differences between the trilobites and other large groups are clearly recognizable, and do not consist of a statement of anomalous characters whose real significance is unknown.

[To be continued.]

Art. IX.—*Preliminary Trial of an Interferential Induction balance;* by C. Barus.

1. The following device is capable, I believe, of a variety of applications in relation to alternating currents and to magnetic induction. The idea underlying the apparatus is briefly this: Let the slender iron cores of two identical helices be placed at right angles to each other, in the same (horizontal) plane and at like distances from the point of convergence. Let the distant ends of the iron cores be rigidly fastened, while the other ends are free to move (expand and contract) in the direction of the axes. Then it is possible to adapt Michelson's interferential refractor in such a way that the fringes are visible whenever the excursions of the free ends of the cores are either zero or vibrating in the same phase, amplitude and period to and from the point of convergence. The fringes vanish more or less fully for all other phases.

Let the two helices be traversed by the same alternating current, and let the reduced length of the electrical conductor between them be negligible and the vibrations in the same phase initially. Then if the reduced length of the conductor be gradually increased, the two vibrations will be dephased and the fringes will gradually vanish. If the lengthening of the conductor be continued until the excitement of one helix is belated one complete period of the vibrating core with reference to the other, the fringes will reappear *caet. par.* with their original clearness. A method of estimating the speed of signalling from one helix to the other is thus given in terms of the period of longitudinal vibration of the vibrating core.

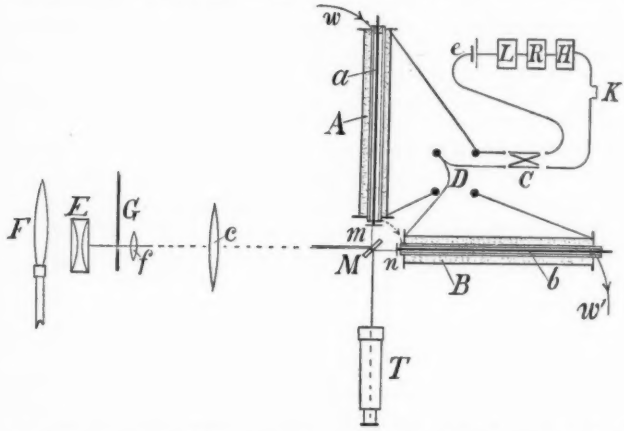
If the helices are not identical, similar deductions apply for the difference of time lag of current behind the electromotive force for the two helices respectively.

Finally vanished fringes are open to observation by stroboscopic methods.

§ 2. The form of apparatus used is shown diagrammatically and largely in sectional plan in the figure. A and B are the two helices and a and b their cores of soft Norway iron. These with the helices are rigidly fixed at the further ends. The cores pass axially through the helices without touching them, and carry small light plane mirrors m and n at their free ends. With the thick plane-parallel plate M, these mirrors make up Michelson's refractometer. Light (thus far furnished by a sodium flame) is emitted by the distant burner F provided with Cushman's sodium collar,* and condensed by

* This efficient device, due to Holbrook Cushman, consists of a layer of filter paper impregnated with sodium carbonate and wrapped around the top of the burner. The sodium flame so obtained is very dense and lasts for days.

the train of lenses *e*, *f*, *c*. As a rule the flame with a single lens would be sufficient and the train is here given to admit of the introduction of the stroboscopic disc *G* when an intermittent beam is wanted. Other small fixed screens are often advantageous. Falling on *M* (preferably covered with a transparent coat of silver), the light undergoes interferential refrac-



tion in the now well-known way. The optical parts of the apparatus are fully described in Michelson's* great memoir, and further reference here is needless. To obtain the interference it is usually sufficient (good glass presupposed) to bring the images of the same small distant luminous point into coindence. Removing *f* and *c*, a small hole in *G* answers the purposes. If the helix *A* and its mirror is fixed, the helix *B* and its mirror must be movable in azimuth and altitude. I found the large round table of an old Kirchhoff spectrometer excellent for this purpose. The helices *A* and *B* were mounted in place of the telescopes, and the mirror *M* on a small adjustable tripod could then be moved on the flat table into position. If the glass is not very good, as is apt to be the case with thin mirrors, *m* and *n*, and ordinary plate glass, it is necessary to find the parts of the plates sufficiently plane, by trial. In general it is best to bring the edges of the mirrors to overlap, in which case the interference figure is of lune-shaped outline and relatively clear. The adjustments may be made with the naked eye. For observations, however, the small telescope *T*,

* Michelson: Valeur du Mètre, Trav. Bureau Int., xi, 1894.

provided with cross-hairs, must be so mounted as to be easily focussed, moved about and inclined.

Whenever a current passes through either of the helices A and B the cores a, b will in general expand, unless the field be very intense. Current for this purpose is furnished by one or more storage cells e, passes through a commutator C and a switch board D, by which either one or both the helices may be put into the circuit. The circuit also contains inductive resistance H, non-inductive resistance R and an interrupter L for intermittent currents. K is a key. As the magnetic expansion due to complete saturation is only a few millionths, the effects of thermal expansion must be excluded. Hence the frame of each helix is a thin shell-like water-jacket. Water arrives at w, passes in a thin sheet between the core and the wire of helix A, then similarly through helix B and leaves at w'. The same temperature is thus obtained for both helices and strong electrical currents passed through them are without thermal effect on the core.

The two helices were wound identically and chiefly for continuous currents. They each consisted of eight layers of No. 21 copper wire with 410 turns in each layer, and they were 37^{cm} long. The diameter of the internal canal was about $0{\cdot}8^{cm}$, and the outer wall of the water-jacket on which the wire was wrapped about $1{\cdot}5^{cm}$. In view of the long helices the enclosed iron cores (about 28^{cm} long, $0{\cdot}6^{cm}$ in diameter) were in a fairly constant field.* Their rear ends were soldered into a rod of brass snugly fitting the box of the helix and rigidly fastened by screws. The front ends were soldered to very thin copper tubes which protruded beyond the helix and served as holders for the mirrors m, n. The cores were made as straight as possible, adjusted symmetrically and coaxially with the helix, leaving a clear space of about 1^{mm} between core and helix. The fastening of the cores is merely suggested in the figure.

When mounted the apparatus must necessarily be placed on a pier or other firm support; but even this is insufficient unless the vibrations are damped at different parts of the apparatus. Thus it is necessary to support the helices from two points near their ends, and independently to prevent transverse vibrations of the core. After many trials I found that a short plug of vasilene in the tubes near the ends m, n was preferable to mechanical devices. Prof. Mayer's important paper should be consulted on all these points.

§ 3. If both mirrors move towards the point of convergence symmetrically and equally, the same number of wave lengths

* Mayer: Phil. Mag. [4], xlvi, p. 177, 1873.

are cut off by both and the interference fringes will not be displaced however fast the mirrors may vibrate. If an appreciable time is spent by the effective current in passing from helix A to helix B, then with increasing retardation the fringes will gradually vanish and gradually reappear when the time of delay has reached the period of vibration of the mirrors. Let the motion of the mirrors m, n be given by $a_1 \sin \omega t$ and $a_2 \sin (\omega t + \theta)$. Then the motion of the fringes is proportional to $a' \sin(\omega t - \theta')$; where

$$a' = \sqrt{a_1^2 + a_2^2 - 2a_1 a_2 \cos\theta} \text{ and } \tan\theta' = a_2 \sin\theta / (a_1 + a_2 \cos\theta).$$

If the amplitudes are equal

$$a' = 2a \sin\theta/2 \qquad (1)$$

If the self-inductions L_1 and L_2 of the two helices are not equal, if, for instance, the cores are chosen of different diameters, the currents in the helices will lag behind the corresponding electromotive forces by different amounts. The result will bring the interference fringes to vanish more and more fully at first, and finally less and less so, as the difference of self-induction increases, till the dephasing approaches one complete period. If θ_1 and θ_2 be the current lag in each helix and if their ohmic resistance R is the same, then

$$\theta = \theta_1 - \theta_2 = \tan^{-1} \frac{L_1\omega/R - L_2\omega/R}{1 + L_1 L_2 \omega^2/R^2},$$

or

$$\tan\theta = \omega R \frac{L_1 - L_2}{R^2 + L_1 L_2 \omega^2} \qquad (2)$$

There are thus two equations, (1) and (2), for θ. If L_2 be made very small $\tan\theta = \omega L_1/R$. Similar results may be obtained for different amplitudes a_1 and a_2, and different values for R.

Equation (1), however, may be supposed to include the retardation due to the external resistances as well as the lag in equation (2). From this wider point of view the fringes will be at *rest* if $a' = 0$ or if θ is an even multiple of π. The motion of the interference fringes will be a maximum or they will vibrate to and fro with greatest intensity when θ is an odd multiple of π.

The criterion is, therefore, visibility and clearness of the fringes, and the method of observation is not continuous.

§ 4. With the object of obtaining a continuous series of data the above stroboscopic disc G was introduced. It is made of very thin tin plate about 40^{cm} in diameter, with a sufficient

number of equidistant small holes cut near the margin. Mounted on an axle and rotated by a small electromotor, it was supposed that the speed could be regulated nearly enough by inserting resistances. I did not have any success with this disc. Though I was able to increase the flashes to 3000 per second, they were never instantaneous enough for the work, even when the holes were reduced to an extreme of smallness. It ought not to be difficult, however, to reach the end in view by replacing the sodium flame F by a hydrogen Geissler tube. The light would have to be analyzed prismatically and the period of intermittance suitably chosen. Michelson* has shown that the lines of the hydrogen spectrum are not well adapted for refined refractometer work. In the present case the number of fringes in question is only a very few (2 or 3), so that I do not think there will be difficulty for this reason.

5. The apparatus being differential in type, is particularly adapted for observing the Joule expansion phenomenon, its variation with the field, with temperature and dimensions of the core, etc. The results of the table are random examples among many data obtained with *continuous* currents. The first column shows the field within the helix, the second and third columns the expansions in millionths of the length of core for each helix separately, and the fourth column the corresponding results when both helices were in circuit. When results differed the mean value was taken. Since the motion of one fringe across the cross-hairs of the telescope corresponds to about $30/10^6$ cm (in view of reflection) and since the iron cores are about 30^{cm} long, the elongation is about 10^{-6} per fringe. Now the motion of less than one-tenth fringe is discernable; hence an elongation of one ten-millionth is easily recognized.

Field dynes/cm².	Expansion × 10^6.			Remarks.
	Core *A*.	Core *B*.	Both.	
4	·0	0·0	0·0	
7	+·2	−0·2	0·0	
11	·3	−0·6	0·2	Incipient shifting.
14	·6	0·6	0·2	
18	·8	−0·8	---	
20	·8	−1·0	0·3	
22	1·2	−1·5	0·4	Continual shifting. No rotation.
30	1·2	−1·2	---	
44	·7	·5	0·2	Much rotation.
100	---	---	0·5	Rotation.
600	---	---	---	Rotation.

* Michelson: l. c., Annex, III.

Taken as a whole, the results of the table agree in character with Bidwell's* interesting investigations. They show that the expansion increases to a maximum, attaining it in a field between 20 and 30 dynes, at which the iron is probably saturated. After this the data are obscured. The present maximum expansions are smaller than Bidwell's and occur at an earlier stage of magnetization. Thus an elongation of 1 to 1·5 millionths was rarely exceeded.

Although my experiments were made in fields as large as 600 dynes, the results above 30 dynes are of no value. For in larger fields than this the fringes showed more and more rotation intermixed with the translation. This indicates that the suspended cores were flexed by the field, or that they contained inherent torsion which in a field gives rise to a Wiedemann effect, or both. Probably flexure supervened. To give an example among many: In a field of 330 dynes the fringes for helix *A* showed clockwise rotation, the fringes for helix *B* counter-clockwise rotation. The two cores together showed a definite translation of about one fringe, without rotation. This would correspond to compensatory flexures,† and in large fields the real phenomenon was masked by this discrepancy.

If the results are studied with reference to weak fields, the curve is found to terminate *abruptly* in the abscissa. No elongation was observable in fields less than about 7 dynes. For fields larger than this, an increment of field less than a single dyne produced an observable change of elongation. This result is sufficiently remarkable to deserve detailed study.

There is a final point to be mentioned. In a field of about 20, in which the elongation of the above rods was most pronounced, the observed effect with a single helix in circuit was such as to correspond to a shifting of the fringes whenever the circuit was closed, with no return of fringes apparent on opening. On closing, about 1·5 fringes visibly and invariably moved across the cross-hairs of the telescope; on opening, the return was either partial or (apparently) absent altogether. I was even able to make over 100 fringes move across the field by continually closing and opening the circuit. On inserting the other helix alone the result was the same but reversed in direction. With both helices in circuit there was but little motion. I was at first inclined to refer this observation to an increase of temperature due to magnetization. The passage of $\frac{1}{2}$ fringe corresponds to an elongation of 5×10^{-7}. The equivalent rise

* Bidwell: See Ewing's Magnetic induction in iron, p. 238; Phil. Trans., 1888, p. 205; Proc. Roy. Soc., xlvii, p. 469, 1890.

† Unfortunately the soft Norway iron obtainable here is not quite straight; and since all mechanical treatment hardens and injures the iron, I was obliged to content myself with the best samples in the lot at my disposal.

of temperature in iron would be 0·04° C., which in case of several hundred repetitions would be otherwise appreciable. Hence this observation, though distinctly marked, must be an illusion and due to the fact that the magnetization takes place much more slowly than the demagnetization. It is a curious feature, however, that for fields above and below the sensitive value in question, continued shifting does not occur.

6. The results obtained are applicable to intermittent currents of low frequency at once. From the dimensions given, the self-induction L of the two helices is not above 0·5 henry, each. If the frequency be kept below 100 per second, the current would not be dephased more than about 0·2 period behind the electromotive force; and there would be no serious interference with visibility from this cause since the partial electromotive forces of each helix as well as the total electromotive force are in advance of their respective currents by the same fraction of a period. For a simple harmonic variation of electromotive force at the source, the impedance introduced at each coil for frequencies, 0, 10, 50, 100 would be about 11, 34, 158, 316, respectively. To produce appreciable expansion of the iron cores one would, therefore, merely have to increase the electromotive forces accordingly.

In the following experiments, however, the current is actually made and broken. Since the extra current is thus evoked and necessarily introduced at the *maximum* of electromotive force, its effect will be a maximum. From the given dimensions one should expect the current in successive intervals of 0·01 sec. each to be 0·20, ·37, ·50, ·60, etc., of the maximum. It will thus be necessary, if the frequency is as high as 100, to use five times the battery power needed in case of continuous currents under the same circumstances. This is also the effective quantity of current whether one or both helices are in circuit, seeing that resistance and self-induction in the two cases increase in like ratio.

In the following table I give the results obtained for low frequencies, using a Foucault interrupter of the usual pattern. The first and third columns show the value of the fields had continuous currents been used; the second and fourth columns the corresponding appearance of the interference fringes ("clear" denoting maximum visibility).

One helix in circuit.		Both helices in circuit.	
Fields (maxima).	Fringes.	Fields (maxima).	Fringes.
18	Hazy	16	all clear.
22	Just vanished	18	clear.
27	Vanished	21	clear.
36	do	26	$\frac{3}{4}$ of face clear.
57	do	34	do.
70	do	40	do.
100	do	49	vanishing.

Conformably with § 5 the fringes vanish much sooner (i. e. for smaller fields) when only one helix is in circuit than when both are inserted. Since only about 30 per cent of the full current is effective, the minimum field producing elongation and, therefore, vibration of the cores is about of the same value as before (§ 5).

It is difficult to give the vanishing point. The fringes do not disappear uniformly over the whole face, but parts of the field of view linger longer than others. This again points to rotation of fringes, parts nearer the axis vanishing last. Many other experiments of a similar kind were made, without, however, adding essentially to the above.

7. The question finally occurs whether the above arrangement is sufficient to test the speed of transmission of an electric signal or impulse from helix A to helix B. The equations for this case were originally worked out by Lord Kelvin* and since by others; but I do not know that much direct experimentation has been given to the subject, seeing that in deep sea cables the leakage obscures the law. As the underlying differential equation is of the same form as that which occurs in heat conduction, many of the electrical problems have virtually been solved in the analytic theory of heat. Thus if the potential at the initial point varies as $\sin 2\omega t$, the distribution of potential along the wire is given by

$$E^{-z\sqrt{\omega}} \sin(2\omega t - z\sqrt{\omega})$$

where $z = x\sqrt{kc}$, x being the distance of transmission from the initial point, c the electrostatic capacity per unit of length, k the electrostatic resistance per unit of length. Thus the speed of transmission of like phases is $2\sqrt{\omega/kc}$, increasing, therefore, as the square root of the frequency of vibration, while

* See Math. and Phys. papers of Sir William Thomson, p. 61 et seq., where the expression for capacity is also given.

the time of transmission ($z/2\sqrt{\omega}$) varies as z already given and proportionally to the square root of the periodic time. Finally the magnitude of oscillation decreases in geometric progression as distance increases arithmetically.

In case of a circuit made and broken as above, the quantity which may be called the retardation a (seconds) has the value

$$a = \cdot 02332\ CRx^2\,10^{-6}$$

where C is the capacity in microfarads per knot, R the resistance in ohms per knot, x the length of cable in knots (185,526^{cm}). The equation would not be changed if all data were referred to the centimeter. The current reaches 50 per cent of its value after the lapse of $6a$ seconds, and its full value (nearly) after about $20a$ seconds, no matter what cable be chosen. Finally the capacity of the cable is $C = \cdot 0486\ Kx/\log D/d$, where D/d is the ratio of diameters of cable envelope and cable core, K (microfarads) the specific inductive capacity of the substance of the envelope.

To test the speed of transmission along a wire with resistance and capacity only, let the wire be wrapped bifilarly and the capacity of the bobbin increased by surrounding the insulation of the wire by a continuous conductor. I will suppose this to be done with silk-covered wire about 1^{mm} in diameter with sheets of tin foil around the successive layers to increase the capacity. Thus if $D/d = 1{\cdot}1$ and $K = 2$, then $C = 2{\cdot}5$ microfarads. Hence the retardation per knot, if the resistance per knot be 40 ohms, is $a = 2{\cdot}3/10^6$, and the current would attain its full value in about 50 millionths of a second, for the first knot of cable. For succeeding knots the conditions are more favorable.

It follows, therefore, that if the above apparatus is to measure retardations along about 1·5 knot of the wire specified, the period of vibration of the iron cores must be of the order of 0·0001 second. In this time the change of phase would be complete and one fringe would pass the cross-hairs.

The point finally at issue is whether the above apparatus can respond to 10,000 vibrations per second. It ought not to be difficult to break the current as often as this, Gordon's* rapid speed break reaching 6000 per second. If the iron cores of the above helices be clamped in the middle with the ends free to vibrate as an elastic solid, longitudinally, a length slightly over 30^{cm} would vibrate with the given frequency. This is about the length of core used above.

On the other hand, it is necessary to wind the helices for

* Gordon: Electricity and Magnetism, p. 49.

smaller self-induction, retaining the condition of identity. Thus if only a single layer of wire is used on the above frame, and if the core of half the above diameter (made tubular or cross-shaped in section) be inserted, the self-induction will be reduced to ·002 henrys, and the impedance for 10,000 vibrations to 126 ohms. The field of this helix is 14 dynes per ampere, and since half this value is just sufficient to elongate the cores appreciably, about 90 volts would be needed to produce the vibration, apart from the favorable condition of resonance. Finally, in view of the large factor $R/L = 750$, after 0·0001 second the extra current has kept the current strength reduced to about 1 per cent of the maximum value. Hence the current must be 100 times stronger than when it acts continuously, $R/L = 750$, requiring 70 volts to maintain it.

To summarize: Setting considerations of mechanism aside, an arrangement of the kind shown above supplied with about 100 volts ought to indicate the retardation along something over a single knot of wire of the high capacity stated, inserted between the helices. This retardation will be exhibited by the passage of one yellow interference fringe across the cross-hairs of the telescope.

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ART. X.—*The Multiple Spectra of Gases;* by JOHN TROWBRIDGE and THEODORE WM. RICHARDS.

IN a recent paper upon the spectra of argon we have shown that the two different spectra of this gas are dependent primarily upon the electrical conditions which cause the gas to glow. The continuous discharge of a high tension accumulator through the gas produces the red spectrum, while the discharge of a condenser, provided that its oscillations are not damped by the resistance of the tube, or other resistance or impedance, produces the blue spectrum.

It becomes now a matter of great interest to determine if the same conclusions apply to other gases, a subject which has already been studied in detail by Wüllner and others. The chief difference between our work and the earlier investigations are: first, the use of a high tension accumulator instead of an electrical machine or Ruhmkorff coil as the source of electricity; and secondly, the introduction of varying ohmic resistance or impedance between the plates of the condenser in order to study the damping of the spark. It is the object of this paper to emphasize anew the importance of the electrical conditions of the circuit, and to call attention once more to the fact that the behavior of most elementary gases is in every respect similar to that of argon.

With regard to the spectrum of nitrogen, it has been known for a long time that two spectra could be obtained by means of appropriate changes in the density of the gas, as well as by the introduction of the condenser; but not all investigators have put the same interpretation upon their results. So varying are the views, that Ångström* and Thalen† believed the familiar channelled spectrum to be due to impurities in the gas. Plücker and Hittorf,‡ Wüllner§ and Salet‖ have proved this view to be false, but they had not at hand the constant current of high tension at our disposal and their nitrogen was obtained from air containing argon, so that a revision of their work promised to be of great interest.

With our Planté battery of ten thousand volts we have obtained the usual two different spectra of nitrogen by varying suitably the electrical conditions of the discharge. By means of a continuous discharge with no spark gap or brush dis-

* Pogg. Annalen, cxliv, 300.
† Bull. soc. chim. (2), xxv, 183.
‡ Roy. Soc., Proc., xiii, 153. Phil. Mag. (4), xxviii, 64.
§ Pogg. Ann., cxxxv, 497, cxxxvii, 337, cxlvii, 321, cxlix, 103, cliv, 149.
‖ Ann. Chem. Phys. (4), xxviii, 52. Hasselberg, Ames and others have also studied the nitrogen spectra.

charge in the circuit through nitrogen under varying pressure, we always obtained the channelled spectrum. The glow in the capillary tube, as well as the positive and negative light, was of a delicate pink color under these conditions; a color not unlike the red glow of argon. When an air-gap, over which the battery discharges in a brush, is introduced into this circuit, the glow becomes more violet in tinge, and the spectroscope shows that the red bands almost if not wholly disappear, while the blue and green ones retain their positions. Under these conditions the capillary tube is filled with a pure blue glow, less intense and vivid than that of the argon, however.

When the condenser is introduced, the whole appearance of the tube is utterly transformed. The blue color of the tube at once changes to a rich bluish green, and the channelled spectrum gives place to bright lines, already well known and mapped. This line spectrum corresponds to the blue spectrum of argon. When the oscillations of the condenser-discharge are damped by means of a suitable resistance or self-induction interposed between the condenser plates, a channelled spectrum reappears; but in this case the glow in the tube is of a bluish white color, the positive and negative lights being of a bright yellow. Whether or not this channelled spectrum is, as it seems, exactly like the one obtained by means of a continuous discharge, photographic measurement will show. This last appearance is probably the usual one obtained by means of the Ruhmkorff coil, for then the oscillations induced by the primary condenser are damped by the impedance of the secondary coil and the resistance of the tube.

The spectrum of hydrogen is usually supposed to consist of four bright lines, Hα 6563·0 (C), Hβ 4861·5 (F), Hγ 4340·7 (G'), Hδ 4101·9 (h), as well as several in the extreme violet and ultra violet.*

Other spectra have been observed also; but owing to the partial understanding of the conditions required to produce them, the voluminous literature† upon the subject leaves a confused idea in the mind of the reader. The continuous discharge of a high tension accumulator through hydrogen gas at tensions varying from 0·05^{mm} to 3^{mm} and more yields a beautiful white glow in the capillary of a Geissler tube, while the strata in the positive and negative light are often alternately pale pink and pale blue. When examined by a spectroscope with a broad slit, the light from this discharge appears

* Ames, Phil. Mag. (5), xxx, p. 48 (1890).

† Ångström, Vogel, Lockyer, Fievez, Wiedemann, Huggins, Wüllner, Hasselberg, Balmer, Grünwald, Villari, Schuster, Salet, Smyth and others. For references see O. Dammer; Anorgan. Chem. i, 369.

to consist of bands similar to that of nitrogen, as well as of bright lines; but when the slit is narrowed every band is resolved into a multitude of sharp lines of varying intensities,* among which the four usual hydrogen lines, although present, are by no means especially prominent. A large capacity is required to change this spectrum into the familiar four-line spectrum which is comparable with the blue spectrum of argon. The change is marked by a sharp alteration in the color of the glow from white to a deep red. In the process, the bluish green line ($H\beta$) as well as the two in the violet, which retain their early position unaltered, become nebulous at their edges;† while the red line Ha remains sharp and clear. The most marked change in the spectrum, however, is the complete obliteration of all the host of other lines covering the whole spectrum, and the obvious contrast between the oscillatory and non-oscillatory spectrum of this gas is quite as striking as in the case of nitrogen, although somewhat different in nature. This four-line deep red glow appears satisfactorily in a tension of gas of about a millimeter,—when the tension of the gas is much higher or lower the resistance is increased, the oscillations are damped, and other lines begin to appear. Curiously enough, however, the damping of the oscillatory discharge does not at first replace all the lines which were extinguished by the introduction of the condenser. At first only a sharp line in the yellow and one in the green begin to appear, and gradually others are added as the impedance is increased.

The relation of these conclusions to the varying spectra of hydrogen observed in stars leads to interesting speculations regarding the nature of the electrical and thermal conditions in the photospheres of these bodies.‡

Each of the halogens gives two spectra, one with and one without the condenser. With iodine, if any of the solid itself is present in the tube, the vapor tension is so soon altered by the heat of the discharge that the oscillatory discharge is damped and the non oscillatory substituted. Hence the former can be obtained only for a few moments.

A tube of helium made by Professor Ramsay, the kind gift of the Hon. R. J. Strutt, gave a brilliant yellow glow under the influence of the continuous discharge, and a brilliant blue with the condenser discharge, but since the bright helium lines remained in each, and every other important line in the blue spectrum proved to be an argon line, it is evident that the oscillations produced no considerable effect upon the helium.

* Smyth, Wied. Ann. Beiblätter (2), vii, p. 286. Wüllner observed this spectrum but did not measure the lines.

† E. Villari, Fievez, and Salet.

‡ E. Ebert, Wied. Ann., liii, 1894.

As Crookes and others have already pointed out, since many gases yield different spectra under the influence of varying electrical conditions, it is evident that the fact of the existence of two well-marked spectra of argon gives not the slightest presumption in favor of the hypothesis that the new gas is a mixture. In order to discover if argon possesses a dual nature, the gas must be split up in such a way that its components give different spectra under like electrical conditions; then alone would the evidence of the spectroscope be of weight in proving the dissimilarity of the several parts.

The results of this work are thus far only those which were to have been expected from a high tension galvanic battery, reasoning from the work of other investigators with the Toepler-Holtz machine. The battery, however, gives a current so admirably constant and so easily regulated as to its tension, that we hope to be able to use it as a means of determining whether the oscillatory discharge produces its effect simply by increasing the temperature, or because of some inherent property in the manner of the discharge.

It is our intention to extend the investigation by the systematic photographic study of the action of the varying discharge upon all the elementary gases in the purest condition, as well as upon mixtures under widely varying conditions of temperature and pressure.

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ART. XI. — *Studies in the Cyperaceæ;* by THEO. HOLM. III. *Carex Fraseri* Andrews, a morphological and anatomical study. (With Plate IV.)

THIS very rare and local plant has a peculiar and striking appearance which at once distinguishes it from most of the other species of *Carex*, and since we have, also, observed several peculiarities in its internal structure, we have thought it worth while to treat this species for itself.

As regards the morphological characteristics of our plant, we have already in a previous paper* called attention to its monopodial ramification. The foliar organs are very singularly developed and represented by four or five scale-like, membranous leaves and one very broad and deep green leaf, being the only assimilating one of the shoot.

The scale-like leaves have long and perfectly closed sheaths, while the single, proper leaf is not sheathing, the base being merely convolute. This leaf is, then, destitute of any sheath and has no ligule, and the one margin or sometimes both are minutely folded, giving the leaf the appearance of being finely serrate along the margin. These characters, the lack of sheath and of ligule, distinguish this species from most, if not all the other representatives of the genus *Carex*. It is true, however, that in some of our very broad-leaved species, e. g., *C. plantaginea*, *C. platyphylla*, etc., the leaf-sheath is very short and breaks open at an early stage, but it is, nevertheless, easily distinguishable while the leaf is still in bud, and the ligule is well developed and persists for a long time. Species with the leaf-margin undulate, as in *Carex Fraseri*, are not known in this genus except that a form of *C. pallescens* L. is occasionally met with, of which the bracts are more or less undulate, hence the distinction of the variety "*undulata* Kze." The question is, now, to decide the proper situation of these two forms of leaves, whether the large, green leaf belongs to the same axis as the scale-like ones. It appears, however, as if the floral bud is lateral, and that it is directly developed from the axil of the large, green leaf, this being the only leaf of the central, vegetative bud. The central bud is, therefore, of a short duration, of about one year only. By examining specimens of this species in the winter-time, the floral buds are observed to be situated exactly as in the other species with monopodial ramification, with the exception that each vegetative shoot has, in *C. Fraseri* constantly, not more than one single, assimilating leaf developed.

* See this Journal, vol. i, May, 1896, p. 349.

By considering the stem above ground, this is not terete or triangular as we are used to find it in the *Cyperaceæ*, but flattened, almost, in its entire length. The inflorescence bears a large number of staminate flowers at the apex, and a number of pistillate ones at the base of the staminate, all of which are supported by broad, hyaline and silvery shining bracts, almost entirely destitute of chlorophyll. The utriculus is large, membranous and much inflated. It encloses the pistil, which (Plate IV, fig. 2) is distinctly stipitate (Stp.) and with the rhacheola (Rh.) extended beyond the pistil. The development of this rhacheola is to be seen in our figure 1, where a very young pistillate flower of *Carex Fraseri* has been illustrated. It has been drawn from a flower at a very young stage, while the entire inflorescence was still inclosed in the bud for the winter. This figure shows the utriculus (Utr.) forming a low wreath and surrounding the three carpels (Carp.); on the front-side of the utriculus is a small, roundish body to be seen (Rh.), which represents the free apex of the rhacheola, being here extended beyond the flower. This fact, the extension of the rhacheola, has, already, been observed in this species by Baillon (l. c.); besides it is far from uncommon in other species of *Carex*, as recorded by the writer in a previous article upon this subject.* In *Carex Fraseri* this processus is most frequently without any rudiments of flowers, but sometimes a few imperfect have been observed.

Another peculiarity of the pistillate flower in this species is the occasional development of four stigmata; besides that Boott (l. c.) has described and figured a flower with two utriculi, thus originating from two separate prophylla, a fact which seems to be exceedingly rare in the *Cyperaceæ*.

But by considering these morphological characteristics of *C. Fraseri* as a whole, there does not seem to be any character important enough for distinguishing it generically from the other *Carices*, inasmuch as the peculiarities of the pistillate flower, the extended rhacheola for instance, is not sufficient for admitting any such distinction. Its most peculiar morphological character is, no doubt, the absence of a closed sheath and ligule in the assimilating leaf.

We will, thereupon, examine the anatomical structure of our plant.

The leaves, the scale-like ones, are membranous and almost destitute of chlorophyll. The epidermis forms, on both faces of the leaf a homogeneous tissue of rectangular cells with the walls slightly undulate. Stomata are either entirely absent or merely present in a very small number on the dorsal face. A

* This Journal, vol. ii, September, 1896, p. 216.

transverse section of one of these scale-like leaves shows us a structure, which in most respects reminds us of a leaf-sheath, viz: the development of large lacunes between the mestome-bundles, the non-differentiation of the mesophyll and the partial absence of vessels in the mestome-bundles, while the leptome-elements are well-developed. The stereome is, also, characteristic, forming large groups on the dorsal face of the leaf underneath the leptome-side of the mestome-bundles; besides it, also, forms isolated groups between the bundles. The corresponding groups of stereome on the ventral face are smaller, and the cell-walls are relatively thin, leaving a large lumen. The free part of the scale-like leaf shows a similar structure, and the free margins consist only of two strata of cells, corresponding to the dorsal and ventral epidermis.

The large, green leaf has a similarly developed epidermis on both faces, but stomata are present in large number on both faces, but most numerous on the inferior, the dorsal face. These stomata show the same, characteristic form as recorded by Schwendener (l. c.), but they are constantly in niveau with the surrounding epidermis-cells. Very characteristic of the epidermis is the total absence of epidermal expansions such as hairs or thorns, which are so common in most of the other *Cyperaceæ*.

There is, however, one kind of epidermal expansions which our plant has in common with the other *Cyperaceæ*, viz: the peculiar silicious cones, which are noted to project from the bottom of the epidermis-cells and often reaching the superior wall. These cones may occur from one to two in each cell (Plate IV, fig. 3), but they are only present in those strata of epidermis which cover the groups of stereome on the dorsal face of the leaf-blade.

We have stated above that the epidermis forms an almost homogeneous tissue on both faces of the blade, excepting a few strata of somewhat narrower cells, covering the mestome-bundles, but this divergency in shape is too small to be of any importance. We should, however, expect to observe quite a considerable variation in some of the epidermal strata, at least on the ventral face of the blade. We know from the numerous and most important writings of Duval-Jouve upon the structure of the *Cyperaceæ* and the *Gramineæ*, that certain strata of the epidermis have usually attained a special development, widely different from the other epidermis-cells, and of which the function is to facilitate the folding or closing of the leaf-blade so as to prevent the surface from being exposed to the strong sunlight, thus protecting the leaf against a too rapid evaporation. These cells were by Duval-Jouve named "bulliform-cells" (Duval-Jouve: Histotaxie l. c.) and they differ

very much from the surrounding cells in regard to their size and shape. They are often developed as vesicles with a rather thick and strongly cuticularized outer-wall, and show a great tendency to collapse, when exposed to excessive drought, while they rapidly swell up again, when brought in contact with moisture. These peculiar cells are, as a rule, located on the superior face of the leaf-blade and they are most often to be observed above the midrib, but also between some of the larger mestome-bundles in several genera, especially in the broad-leaved species.

It is easily understood, that being located where they are, these cells by collapsing naturally force the blade to become folded either as simply "conduplicate" or as "convolute." In the genus *Carex*, of the species which have been examined, this form of cells has never been observed to be missing. We have figured the most common shape and size, which these bulliform cells attain in *Carex*, e. g. figure 5, which is from *C. virescens* Muhl., a species with leaves of ordinary width, and which grows in localities not exposed to excessive drought or moisture. In some species, which inhabit places exposed to heavy winds, and which are especially characteristic of the sand-dune vegetation, the bulliform-cells are especially developed and are even supported by several strata of similar, but smaller cells, all constituting a typic closing-apparatus for the leaf-blade. Figure 6 shows such layers of bulliform cells from the leaf of *C. trinervis* Degl., a common sand-sedge from the west coast of Europe. The very narrow-leaved *Carices* have, on the other hand, not the bulliform cells so well differentiated, as for instance in *C. exilis* Dew. (fig. 4), besides similar marsh-sedges, as *C. diœca* L., *C. gynocrates* Wormskj., etc.

But our *C. Fraseri* is entirely destitute of any such bulliform cells on either side of the blade, which is the more surprising when we consider the extraordinary width of the leaves; the plant seems, therefore, to be very poorly adapted for existing outside of the damp and shaded ravines where it usually occurs.

In considering now the structure of the other tissues which compose the leaf, our plant does not differ in any essential respect from the other species of *Carex*. The mesophyll forms a homogeneous tissue all through the blade, and it consists of polygonal cells, which are closely packed on both faces of the leaf, while the central part of the leaf-blade is traversed by broad lacunes, which are only separated from each other by the mestome-bundles and the adjoining mesophyll.

Very distinct from the mesophyll is the thin-walled parenchyma-sheath, which partly surrounds the mestome-bundle, at least on the sides, extending from the stereome of the superior

face of the blade to that of the inferior. This parenchyma-sheath is not green in our plant, but colorless.

The mestome-bundles are, furthermore, surrounded by a rather thick-walled mestome-sheath (M. S. in fig. 7) which forms an uninterrupted ring all around the leptome and hadrome. The group of leptome is very well differentiated and the hadrome contains a larger number of vessels, especially ring-vessels, than is usually observed in *Carex*. On both faces of the mestome-bundles are groups of stereome (St. in fig. 7) which show the same structure as generally known in this genus. This tissue, the stereome, forms also an isolated group in the leaf-margin itself.

One feature seems, however, somewhat striking, when we consider a number of transverse sections from the entire width of the blade, viz: the uniformity in size and development of the mestome-bundles, at the same time as we observe the equality in thickness of the mesophyll between the mestome-bundles. There is, generally, in the broad-leaved species of *Carex* a distinct difference to be found in regard to the size of the mestome-bundles, besides that the mesophyll often becomes constricted in certain places so as to leave room for groups of bulliform-cells, which as stated above are absent in our plant. The sections of the leaf, as described above, were all taken from the middle of the blade, and we will now examine the very base of the same leaf, which in the other *Carices* forms a closed sheath, but which is free and merely convolute in our plant. Such sections, taken from the base of the leaf, show a structure much like that we have described for the broad part of the blade. We merely note that the groups of stereome are longer and much more narrow, besides that their cells have a considerably larger lumen. The mestome-bundles themselves show a somewhat weaker development, and the lacunes are much reduced in size from what we have observed higher up in the leaf.

The structure of the utriculus may be described in this place. Its thin, bladderlike texture (fig. 8) is due to the extraordinary thin cell-walls of not only the epidermis, but also of the mesophyll underneath this. A few mestome-bundles are observable, all of which are very weakly developed, especially in regard to the hadrome-part, and the cells of the supporting stereome are relatively very thin-walled. Utriculus, so far, corresponds to Wilczek's second type (l. c.), characterized by its thin structure and the non-differentiation of the mesophyll.

The pericarp shows a similar thin texture and is composed of three tissues, viz: a very thin-walled epidermis, a stratum of three rows of relatively thick-walled sclereids, and finally a layer of horizontally stretched cells, which form the inner

coating of the pericarp (fig. 9). The stem above-ground, which at its apex bears the inflorescence, is in our plant flattened almost in its entire length, except at the base, where it is strictly cylindric. The anatomical structure is, however, the same whether we examine the cylindric or the flattened part, except in regard to the pith, which is broken in the upper part of the stem, rendering this hollow; this character, the hollow stem, is rather uncommon in the *Carices*, although it has been observed in certain species. The epidermis of the stem is very uniform and thin-walled; it possesses the interior silicious cones, but is like the epidermis of the leaf, entirely destitute of exterior expansions. The bark-parenchyma is quite large and consists of very thin-walled roundish cells, which gradually pass over into a large tissue of polygonal cells, which occupy the greater inner-part of the stem and which represents a typical pith.

Mestome-bundles are quite numerous and form two concentric rows, viz: an outer row of large bundles, supported by heavy layers of stereome, especially on the outer side and bordering immediately on the epidermis, while the inner row of mestome-bundles is only supported by a very small layer of stereome. The bundles of the inner row are smaller and are imbedded in the bark in alternation with the mestome-bundles of the outer row. Concerning the structure of these bundles, the larger ones are exactly built up as those of the leaf, except, of course, that no mestome-sheath is developed, this being always confined to the leaf-bundles.

The rhizome of our plant is very short on account of its cespitose growth, and the ascending shoots do not push out in any considerable distance from the main rhizome. The interior structure corresponds in most respects with that of the stem above ground, viz: the development of the bark, the arrangement of the mestome-bundles in two concentric, alternating rows, and finally by the central pith. We notice, however, some characters in the rhizome by which this differs from the stem above ground, viz: the presence of an endodermis, surrounding the bundles, thus separating them from the proper bark-parenchyma. The bark itself is in the rhizome composed of rather thick-walled cells, all of which contain deposits of starch; the endodermis consists of roundish cells, which are thickened all around. As regards the mestome-bundles these are more or less surrounded by stereome, the cells of which are not very thick-walled. We notice here, as in the stem, that the two rows of bundles show a different development in regard to their relative size, besides that the larger are here perihadromatic, i. e. the leptome is central and surrounded by the elements of the hadrome. The central part of the rhizome is occupied by a thick-walled pith, the cells of which contain

starch. Considered as a whole, the structure of the rhizome of our plant agrees in most respects with that of a number of other species, which by Laux (l. c.) has been classified as representing his eighth type.

The roots of *Carex Fraseri* are numerous and cover the short rhizome with a dense mass of long and strong fibers. The interior structure of the root in the *Cyperaceæ* has long since been most ably discussed by Treub (l. c.) and Klinge (l. c.), whose comparative studies have given us the principal features by which the *Cyperaceæ* may be distinguished from the *Gramineæ* and other families of the *Monocotyledoneæ*. We have learned, for instance, that the inner bark cells in the roots of the Grasses collapse radially, while tangentially in the *Cyperaceæ*. Another and very distinct character is that in the *Cariceæ* the protohadrome borders immediately on the endodermis, thus interrupting the pericambium. The root of our plant shows now the following structure: an epidermis of usual form; a bark-parenchyma of about ten layers of roundish, thick-walled cells, some of which collapse tangentially and form thereby lacunes of very considerable width. The innermost layer of the bark is differentiated as an endodermis, the cells of which are thickened so as to represent a typical U-endodermis. We observe, thereupon, the pericambium, which in our species forms a completely closed ring, without being interrupted by the protohadrome. This fact seems to form a very singular character of our plant, thus differing from all the other *Cariceæ* which have hitherto been examined.

The central-cylinder is occupied by six relatively large groups of hadrome in alternation with groups of leptome, besides the distinct but small elements of the protohadrome, situated close to the pericambium. The greater part of the central cylinder is, however, occupied by a mass of conjunctive tissue,* which surrounds the vessels and forms in the center of the root a very compact tissue of rather large and thick-walled cells, the cell-walls being strongly lignified.

If we will now consider these morphological and anatomical characters, which we have observed in *Carex Fraseri*, it may not be denied that this species is one of the most remarkable in the whole genus, at least of those which, so far, have been examined by the various authors.

The monopodial ramification of its rhizome with its single assimilating leaf destitute of sheath, ligule, epidermal expansions and bulliform-cells in connection with its flat and hollow stem, besides the uninterrupted pericambium of the root, constitute a structure that seems almost unique in the family of the *Cyperaceæ*.

* Russow's "Geleitzellen" (l. c.), Klinge's "Leitzellen" (l. c.) and Van Tieghem's "Cellules conjunctives" (l. c.).

Some of these characters, considered by themselves, may even prove sufficient for the distinguishing of this singular species.

Washington, D. C., December, 1896.

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EXPLANATION OF PLATE IV.

FIGURE 1.—A young female flower of *Carex Fraseri*. Carp: the carpels; Rh: the rhacheola; Utr: the utriculus.

FIGURE 2.—Mature caryopsis of *C. Fraseri*. Rh: the rhacheola; Car: the caryopsis; Stp: the stipe.

FIGURE 3.—Cells of the epidermis of the leaf of *C. Fraseri*, showing two internal, silicious cones. St: stereome.

FIGURE 4.—Bulliform-cells of the leaf of *Carex exilis*.

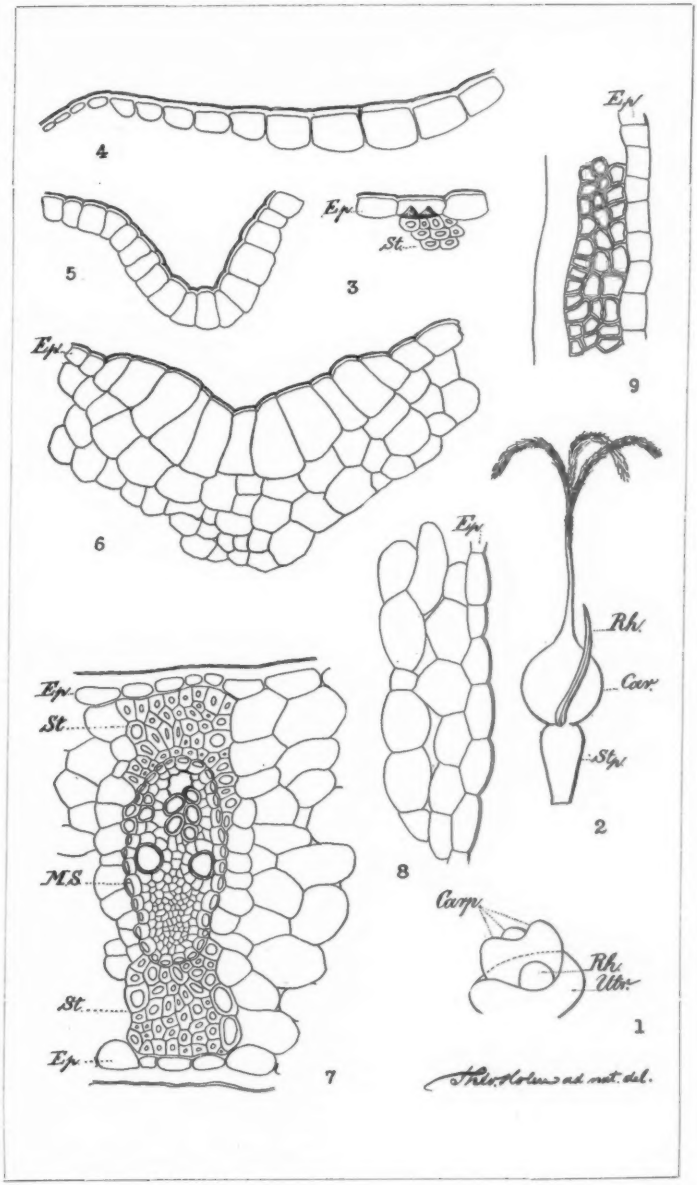
FIGURE 5.—Bulliform-cells of the leaf of *C. virescens*.

FIGURE 6.—Bulliform-cells of the leaf of *C. trinervis*.

FIGURE 7.—Mestome-bundle of the green leaf of *C. Fraseri*. Ep: epidermis; St: stereome; M. S: mestome-sheath; transverse section

FIGURE 8.—Transverse section of the utriculus of *C. Fraseri*. Ep: epidermis.

FIGURE 9.—Transverse section of the pericarp of *C. Fraseri*. Ep: the exterior, proper epidermis.


4
5
Ep.
St.
3
Ep.
9
6
Ep.
Ep.
Rh.
Coor.
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2
8
Ep.
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MS.
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Carp.
Rh.
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Hoeg. Holmes ad. nat. del.

Art. XII.—*A Simple Instrument for inclining a Preparation in the Microscope;* by T. A. Jaggar, Jr.

The instrument* here described was devised for use in petrography, especially in connection with the Michel-Lévy† and von Fedorow‡ optical methods of determining feldspars. The device may be of service to microscopists in other fields as well, where it is frequently necessary to examine in reflected light the surface of objects, whose relief above the object-glass makes tipping imperative if one desires to view the preparation on all sides.

In the study of thin sections of rock in the polarizing microscope, the constituent minerals are sliced on planes bearing usually no definite relation to the optical symmetry of the individual crystals; in order to obtain sections parallel or perpendicular to directions of optical constancy in particular minerals of such a rock section, it has been necessary, in the past, to seek out individuals whose orientation chanced to give the results desired, or to average a number of approximately accurate sections, or to isolate the mineral and grind special sections oriented with reference to known cleavages or crystal faces. By using the so-called "Universal Stage," which permits rotation of the object-glass about two axes at right angles to each other, von Fedorow has shown that a crystal section may be oriented at will with reference to the polarization plane of the nicols, by simply inclining it, first in one direction, then in a second at right angles to the first, until at length the desired optical effect is observed.

For certain measurements of extreme precision in microscopical crystallography, the graduated circles of the universal stage are indispensable: but for the determination of the feldspars by symmetrical extinctions, or for conoscopic work, in petrography, all that is required in practice is the means of tipping the slide with delicacy in any azimuth at will. An instrument for this purpose should be simple, inexpensive, easily manipulated, adaptable to any microscope and instantly removable; to meet these requirements the instrument here described has been constructed.

The accompanying figure (fig. 1) shows the construction of the instrument in vertical section and plan, natural scale. It is

* The author's model was made by C. Milton Chase, mechanician, 45 Cambridge st., Boston, Mass. The Bausch and Lomb Optical Co, of Rochester, N. Y., have completed a new model, adaptable to the stage of any microscope, when size and distance apart of clip-holes are specified.

† A Michel-Lévy: Étude sur la détermination des feldspaths dans les plaques minces, au point de vue de la classification des roches. Paris, 1894.

‡ E. von Fedorow: Universal-(Theodolith-) Method in der Minéralogie und Petrographie. II. Theil: Krystall-optische Untersuchungen, Zeitschrift für Krystallographie, etc., xxii, 229–268, 1893.

simply a clip (*c*) for the object-glass, supported 15^{mm} above the surface of the stage by a ball-and-socket joint (*b*); a long key (*k*), fitting a triangular aperture (*h*) in the clip-arm (*a*) from

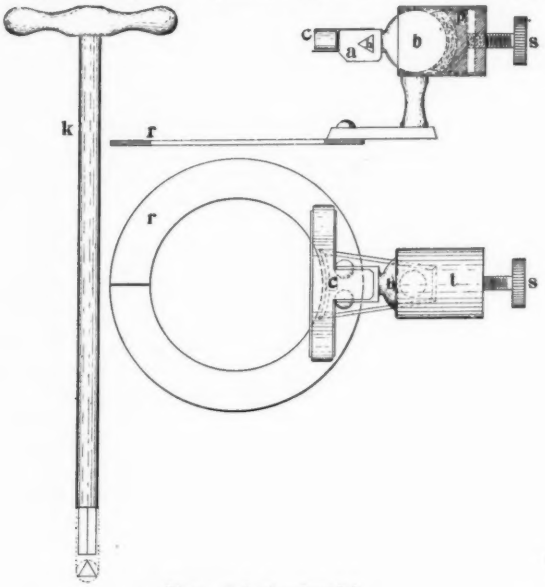


Figure 1 (natural scale).

either side, secures delicacy of manipulation and enables the operator to incline his preparation in any direction by a simple movement of the fingers. A thumb-screw (*s*) in the end of the barrel (*t*) that serves for ball socket, permits adjustment of the tension on the ball by pressure on a brass plate (*p*) faced with cork, which fits the surface of the ball.* In the model figured, the foot-ring (*r*) fits the center of the Fuess mechanical stage, and the rectangular movements of the latter allow ample horizontal adjustment, for bringing different portions of the section into the visual field. The foot of the new model (fig. 2, see foot note p. 129) is made adjustable to the clip-holes of any stage, and the elevated clip attached to the ball-and-socket is of such form that free horizontal movement of the object-glass by hand is possible in all directions; furthermore, the foot-plate is so shaped that in special cases it may be simply slipped under the ordinary clips, and thus held in any desired position.

* This arrangement was suggested to the writer by Professor Goldschmidt's two-circle contact goniometer, where the crystal is centered by a ball-joint and key: v. this Journal, Oct., 1896, p. 285, On Crystal Measurement by means of Angular Coördinates, and on the use of the Goniometer with two Circles; by Charles Palache.

The chief uses of this instrument in petrography are the rapid determination of maximal and minimal extinction and absorption values, the orientation of feldspar twins for deter-

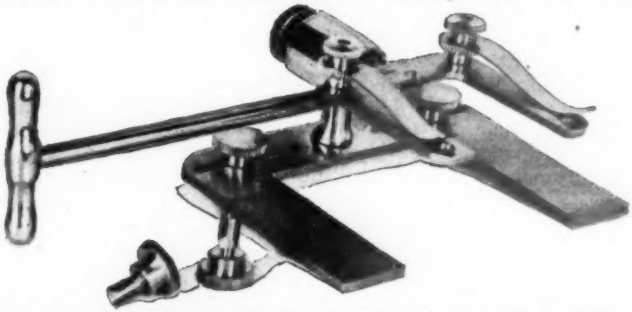


Fig. 2. New model of instrument, showing revised form of foot-plate, with sliding posts adjustable to clip-holes of any stage; an extra pair of these posts shown at the left. Key is in position. The clips may be inserted in all four corners of the elevated clip-plate, and thus turned backward or cross-wise.

mination by Michel-Lévy's method, and the inclination of the section to give well-defined interference figures in convergent light. This latter use has been tested by the writer with a section of calcite cut parallel to the face of the cleavage rhombohedron R (10$\bar{1}$1). The interference figure given by this section, when placed horizontally in the microscope in convergent polarized light, is a black bar, representing one arm of the basal cross, and a small arc of two of three faintly defined chromatic rings on the extreme border of the field. If we now incline the section in the ball-and-socket clip, the *complete cross and rings* may be brought into the field and accurately centred, thus bringing the *c* axis into coincidence with the axis of the microscope. This implies rotation of the section through an angle of over 44°, which is about the working limit of the instrument, and is of course far greater than would usually be required.

For this work, where very high powers are used, a tube must be provided for raising the conoscopic condenser 15^{mm} to the level of the elevated object-glass. In addition it is desirable that this condenser be mounted in a steeply conical cell, in case any considerable tipping of the section about its apex is required; the high-power objectives offer no obstruction in this respect, as they are usually mounted in cells sufficiently tapering. For interference figures from mineral sections where such high magnification is unnecessary, a special long-focus conoscopic combination of objective and condenser is recommended, as these allow ample space for free inclination of the object-glass.*

* R. Fuess in Berlin makes such a combination for use with the Fedorow Universal Stage: v. Ergänzungen zu den Preis-Verzeichnissen 1891 und 1894, R. Fuess, 1895, p. 18, No. 14, last paragraph.

ART. XIII.—*Nocturnal protective coloration in Mammals, Birds, Fishes, Insects, etc., as developed by Natural Selection*;* by A. E. VERRILL.

MUCH has been written in respect to the imitative and protective colors of these groups, as seen by daylight, and the bearing of these facts on natural selection is well known. Very little attention has been paid to their colors, as seen by twilight, moonlight, and starlight. Yet it is evident that protection is more needed during the night than in the daytime, by a very large number of species. This is the case with those that move about in search of their food at night, as is the habit of numerous forms of small mammals, such as rodents (rats, mice, arvicolæ, etc.), insectivores (moles, shrews, etc.), many herbivores, various marsupials, and members of other orders. Many carnivorous species, which seek their prey at night, will also find advantages in such protective colors, for thus they will more easily escape the notice of their prey. Hence many nocturnal carnivores are black or nearly so, as the mink, fishes, some bears, etc. The same principles will apply to birds, reptiles, fishes, and to insects, both in their larval and adult states, for many members of all these groups are very active at night and hide away in holes or beneath dense herbage by day. Moreover, large numbers of birds, fishes and insects, that are active by day, rest in exposed situations at night, and are thus liable to be destroyed by nocturnal enemies. Most small birds roost in trees, bushes, or reeds, and therefore need protection while sleeping. Most small fishes, that are quiet at night, rest among sea-weeds, grasses, and stones, or else directly upon the bottom, exposed to the attacks of many nocturnal carnivorous species. The struggle for existence is severe among such species. It is to be expected, therefore, that instances of nocturnal protective coloration will become numerous when looked for. The chief object of the present paper is to call the attention of more observers to this subject.

In many cases the same colors are equally protective in daylight and at night. This is the case with the green colors, so often seen in the plumage of birds that live among foliage, and with the various shades of brown and gray,—common colors of birds, and mammals that live on the ground, among rocks or dead leaves, and of those that live on or among tree trunks. The same applies to the white colors of mammals and birds in winter and in the arctic regions. But there are

* Abstract of a paper read before the Morphological Society, Dec. 30, 1896.

many colors that are not in the least protective by day, yet are eminently so by night. In general, the black and very dark colors, common in mammals, birds, and insects, are protective at night and not by day. One of the most obvious effects of moonlight is to give very strong or black shadows, in which black or dark animals become invisible, or nearly so. This invisibility is often increased by sharply contrasted stripes or patches of white or light yellow, which look like patches of moonlight falling across a dark shadow, and thus serve to break up the outlines of bird or beast that might otherwise be recognized. Transverse black or dark brown bands on fishes that rest among eel-grass or sea weeds, tend to render the outlines of the fish indistinct, because they look like the shadows and shaded surfaces of the weeds. Black fins and tails have a similar effect, in concealing or destroying the outline of fishes. The striped colors of the tiger have the same effect when it lives among the stalks of reeds, etc., and is probably much more effective in twilight or moonlight than by day. The same is true of the spotted pattern of the leopard, panther, and jaguar.

A great number of small nocturnal mammals, belonging to diverse groups, have dark gray and grayish-brown colors (mouse-colors) which are highly protective at night, but are usually not at all so in the daytime, for such colors are conspicuous among the green herbage which they frequent, and on which most of them feed. Moreover, nearly all such mammals hide away in holes in the daytime. I have noticed that our common meadow mouse (*Arvicola*) which is very dark gray, is scarcely to be seen even in a moonlight night, in localities where it is very abundant among grass, and when large numbers are so near that the sound made by their teeth in feeding is very evident. Among insects there are multitudes of instances of colors that are evidently nocturnally protective and which can be explained only on the basis of natural selection, favoring the variations in color that are in this way most useful. Such colors may or may not be more or less protective in the daytime. Frequently they appear to be just the opposite of protective in the daytime. Thus many butterflies have bright colors that are very conspicuous by daylight and which do not in any way match their customary surroundings. This applies to those species that are black or dark blue, striped or blotched with white, yellow, or orange, and to many species that are spotted or striped with red, orange, and black on the upper surface of the wings, and often also beneath, so that they are conspicuous whether flying or at rest. Their active habits and acute senses probably give them fair protection by day. At night, when resting with the wings folded, the colors

of the under side of the wings usually blend very perfectly with that of the flowers on which they roost. Many of our species of *Argynnis* and allied genera are marked with red, orange, and brown, while there are bright silvery patches on the under side of the wings, which are exposed when at rest. I have observed that these butterflies become very inconspicuous in the moonlight, when sleeping on the goldenrod and other favorite flowers, and that their silvery spots imitate very closely the dew-drops that surround them.

Numerous nocturnal insects that live on the ground are black or dark brown, which are colors that are protective only at night. This is true of most ground beetles, many crickets, cockroaches, ants, etc. Many of these insects hide away in the daytime, so that no protective colors are then needed. But many insects that are exposed both during the day and at night have acquired green or yellowish colors that are protective at all times, when living among foliage. Green grasshoppers, katydids, etc., are examples.

In general, patches, stripes, or spots of strongly contrasted dark and light colors are more likely to be of use by moonlight than by daylight, whether on birds or insects. Reptiles are to a large extent diurnal in their habits and many kinds hide in holes and crevices when at rest, so that our native species of this group appears to afford few good instances of evident nocturnal protective colors, though many may occur when the habits of tropical species become better known. Among nocturnal amphibians protective colors are common, and in many cases they appear to be exclusively for nocturnal protection. Our native nearly black species of salamanders (*Amblystoma punctatum* and *A. opacum*) have conspicuous spots or blotches of white or light yellow. It is evident that these colors have been acquired by natural selection in consequence of the nocturnal protection that they afford.

ART. XIV.—*Nocturnal and diurnal changes in the colors of certain fishes and of the squid* (*Loligo*), *with notes on their sleeping habits*;* by A. E. VERRILL.

WHILE investigating the nocturnal habits and colors of some of our native marine fishes, in 1885 to 1887, at Wood's Holl, Mass., in the laboratory of the U. S. Fish Commission, of which I had charge at that time, I made the unexpected discovery that a number of species had the peculiar habit of assuming, while sleeping, a style of coloration quite unlike that seen in the daytime. Numerous other duties prevented me from making as many observations of this kind as I wished, at that time, nor have I since had opportunities to continue them. Therefore I have decided to publish these incomplete observations, with the hope of inducing other naturalists to continue such studies in some of the various zoological stations that are now established.

Most of my observations were made late at night, between midnight and 2 o'clock A. M., when everybody else had retired. The gas jets near the aquaria were turned down so low as to give barely light enough to distinguish the forms and colors of the fishes. Under these conditions, by using great care not to cause any jar of the floor, nor sudden movements of any kind, I succeeded in observing many species asleep. Most fishes sleep very lightly and are aroused by almost imperceptible vibrations of the air or water. Some of these fishes took unexpected attitudes while asleep.

In many cases the change of color from that seen while awake, or in the daytime, consisted in a simple increase in the depth or intensity of the colors, the pattern of colors remaining the same. This was the case with several species of flounders. Those that are spotted or mottled with dark pigment showed their markings much more strongly, or in greater contrast with the ground-color, than by day. Several species of minnows (*Fundulus*) which are marked either with longitudinal or transverse dark bands, have these markings more decidedly black and better defined than by day. The same is true of the king-fish (*Menticirrus nebulosus*), in which there are obliquely transverse dark stripes that come out more strongly at night than by day.

The black sea-bass (*Serranus furvus*) and the sea-robins (*Prionotus palmipes* and *P. evolans*) presented the same phenomena. Several species of trout (*Salvelinus fontinalis*, etc.) were observed to become much darker at night than in the daytime, but I was not sure that any of those observed were asleep at the time.

* Abstract of a paper read before the American Morphological Society, Dec. 30, 1896. These observations were also communicated to the Connecticut Academy of Sciences, in 1888, but were not published.

It is well known that trout, flounders, and some other fishes are able to change their colors, even in the daytime, according to the color of their surroundings. Therefore a darkening of the colors at night is to be expected, even if not asleep. But in all the cases mentioned above the nocturnal change of color is of a protective character, as explained in the preceding article.

Other fishes, however, show much more remarkable changes. Among these the scup or porgy (*Stenotomus chrysops*) is one of the best examples. This fish, when active in the daytime, usually has a bright silvery color with iridescent tints. But at night, when asleep, it has a dull bronzy ground-color and the body is crossed by about six transverse black bands. When one of these fishes, with this coloration, was awakened by suddenly turning up the gas, it immediately assumed the bright silvery colors belonging to its daytime dress. This experiment was repeated many times, on different individuals, with the same result. As this fish naturally rests among eel-grass and seaweeds, the protective character of its nocturnal colors is obvious.

A common file-fish (*Monacanthus*, sp.) was observed that presents a very decided change in color pattern. This species, in the daytime, is mottled with brown and dark olive-green, and the fins and tail are a little darker than the body, but when asleep, at night, its body becomes pallid gray or nearly white, while the fins and tail become decidedly black. These colors are decidedly protective at night, or in a feeble light, among rocks and weeds, where it lives. This and other species of file-fishes, when sleeping, would usually rest on the bottom with the back leaning against the glass of the aquarium or against a stone at a considerable angle.

The common tautog or black fish (*Tautoga onitis*) has the curious habit of resting upon one side, half buried among gravel, or partly under stones, and is often curved in strange positions. It is easy to imagine that the flounders originated from some symmetrical ancestral form that acquired, like the tautog, the habit of resting upon one side, at first only when sleeping, but afterwards continually, owing to the greater protection that this habit and its imitative coloration afforded. The one-sided coloration and the changes in the position of the eyes, etc., would gradually follow in accordance with well known laws of evolution.

The common squid (*Loligo Pealei*) was observed sleeping on several occasions. At such times it rests in an inclined position, on the tip of its tail and on the basal parts of the arms, which are bunched together and extended forward, so that the head and anterior part of the body are raised from the bottom, so as to give room for breathing. The siphon tube is then turned to one side. Under these circumstances the color is darker and the spots more distinct than when it is active, owing to the expansion of the brown and purple chromatophores.

Art. X V. — *The* Stylinodontia, *a Suborder of Eocene Edentates;* by O. C. Marsh.

In the autumn of 1873, the writer obtained in the Eocene deposits of Wyoming the remains of an extinct mammal of great interest. The most striking feature was the lower molar teeth, all essentially alike, and inserted in deep sockets. They were nearly cylindrical in form, and all grew from persistent pulps. The outer and inner faces were covered with a thin layer of enamel. This type specimen was described by the writer, in this Journal, vol. vii, p. 532, May, 1874, under the name *Stylinodon mirus*, as representing a new genus and species. The affinities of this new form, so far as then determined, were recorded as follows:

"These specimens resemble in some respects the corresponding parts of the genus *Toxodon* Owen, from the Quaternary of South America; but may, perhaps, have some more affinities with the Edentates."

The writer subsequently made this new form the type of a distinct family, the *Stylinodontidæ*, and placed it under the order *Tillodontia* (this Journal, vol. ix, p. 221, March, 1875), and this reference, instead of the original suggestion as to its affinities with the Edentates, has been generally followed.

Fragmentary remains of the genus *Stylinodon* were subsequently obtained by the writer from time to time, in essentially the same horizon, but none of them threw much additional light on the affinities of this peculiar form. A fortunate discovery, in the spring of 1882, at a new locality, was a considerable part of the skull and skeleton of a second specimen apparently of the same species, and this material seemed sufficient to determine definitely the systematic position of *Stylinodon*, as soon as the specimen could be fully prepared for investigation. Owing to a pressure of other work, it was not until ten years later that this specimen was ready for the artist, and careful drawings made, when the Edentate affinities of the animal became more strongly apparent. The problem, however, was not a simple one, and the relation of the genus to other allied forms required careful consideration.

In an interesting paper recently published, Dr. J. L. Wortman discusses the affinities of this family, and presents an argument in favor of their being true Edentates.* This announcement makes it more important that the type specimen of the genus *Stylinodon* be figured, and that the second more perfect specimen be also illustrated and described, and this is the main object of the present communication.

* Bulletin American Museum of Natural History, vol. viii, pp. 259–262, 1896.

The Skull and Teeth.

Figures 1 and 2, below, represent respectively a portion of a large front incisiform tooth of the lower jaw of *Stylinodon*, and several of the adjacent molar series, all natural size, and pertaining to the original type specimen of *Stylinodon mirus*. The peculiar sculpture of the enamel of the anterior tooth, showing both the longitudinal grooves and the transverse lines of growth, is a characteristic feature of these teeth. In the molars, the two bands of enamel, external and internal, show markings similar, but less distinct. The large front tooth is apparently from the left side, the enamel shown being thus on the outer face. The other specimen containing the molar teeth is part of the right lower jaw, with the inner face removed, showing the base of the teeth. The sockets of six of these are represented in figure 2, and behind them one more may be seen in the inner part of the jaw, making together seven in this series, all of similar form and size. The lower jaw containing these eight teeth was short, deep, and massive, with a strong coronoid process, the base of which was in advance of the posterior teeth.

In the second specimen of *Stylinodon* already mentioned, the lower jaws agree in all respects with the type. The seven molar teeth have the same position and proportions as in that specimen. The roots of the large incisiform teeth extended backward as far as the base of the penultimate molars. The condyle of the lower jaw is massive and transverse, the articulation looking upward. Its motion was not limited by a postglenoid process. The posterior margin of the jaw above the angle is thickened into a distinct process, which is somewhat incurved. The lower jaw is especially deep below the last molars, and the entire ramus is robust. The teeth of this genus and the great depth of the jaw below the last molars will distinguish it from *Dryptodon*, described by the writer from a lower horizon.

The skull of *Stylinodon* is short and massive. The temporal fossæ are especially large, and are separated above by a high ridge. The brain cavity was small. The occipital plane is narrow, and the sides converge above and meet at the junction with the sagittal crest. The occipital condyles are small, and there are no distinct paroccipital processes.

The Vertebræ.

The cervical vertebræ of *Stylinodon* are well shown in figure 3, below, which represents the series in the natural position essentially as found. The centra are very short, with the articular faces nearly flat. The axis has a long neural spine directed backward, but the succeeding cervicals have only rudimentary spines, as indicated in the figure.

The first dorsal vertebra has a very high, strong spine, as shown in figures 3 and 4. The other anterior dorsals have also elevated neural spines, and nearly flat articular faces on the centra.

The Scapular Arch.

The scapula of *Stylinodon* is narrow, with the acromion projecting but slightly below the glenoid fossa, as shown in figure 5. The posterior border is not expanded. The anterior portion is somewhat wider than the posterior, and there is no coracoid process. There is a well-developed clavicle. This is of moderate size, with the shaft somewhat flattened. It articulated above with the lower end of the acromion, and below with the sternum, but is not represented in the figures.

1. 2.

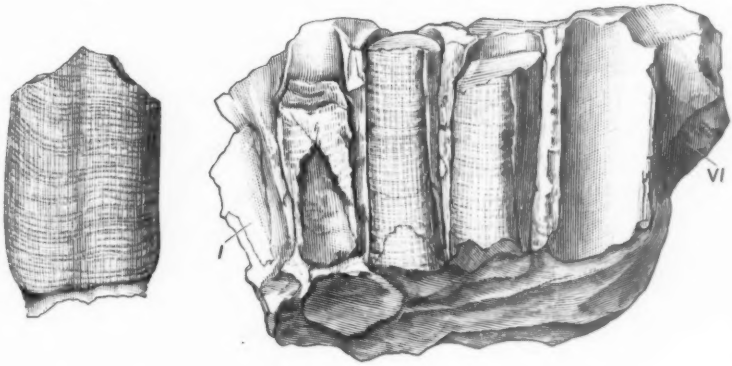


FIGURE 1.—Left incisiform tooth of *Stylinodon mirus*, Marsh; outer view.
FIGURE 2.—Molar series of right lower jaw of same individual; inner view. I, socket of first premolar; VI, socket of penultimate molar.
Both figures are natural size.

The Fore Leg.

The fore leg of *Stylinodon mirus*, as represented in the second specimen above mentioned, is shown in figure 5, one-fourth natural size, with the scapula (*s*), the whole nearly in the position in which it was found. The humerus (*h*) is seen in this figure from the outside, and its connections above and below are clearly indicated. As this bone is especially characteristic, both of the genus and to a certain extent of the order, it is important to present here all its typical features.

3.

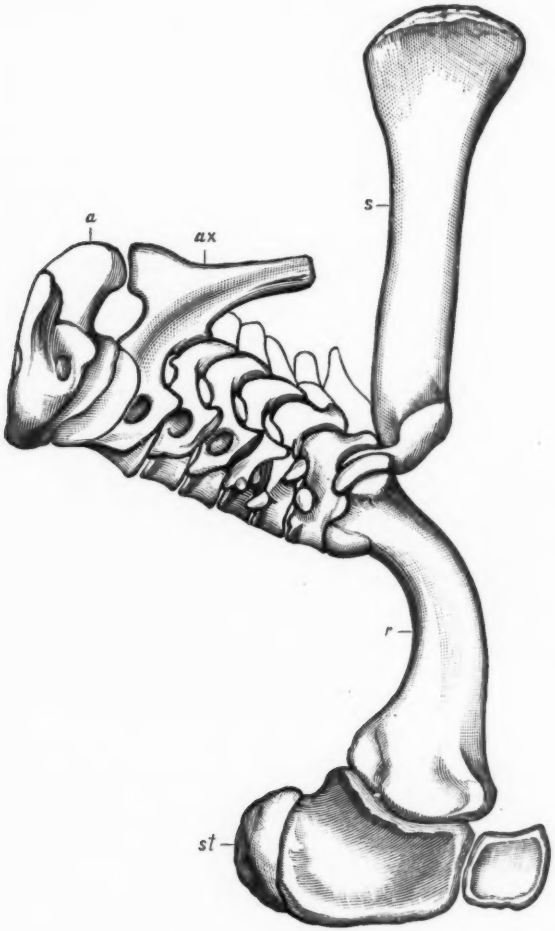


FIGURE 3.—Cervical vertebræ of *Stylinodon mirus*, with first dorsal vertebra, rib, and sternum, in position; seen from the left. One-half natural size. *a*, atlas; *ax*, axis; *r*, rib; *s*, spine of first dorsal vertebra; *st*, sternum.

These are seen to good advantage in figures 6 and 7, where the bone is represented one-half natural size. These figures render a detailed description unnecessary. This bone, like all those of the skeleton, is solid, there being no medullary cavity.

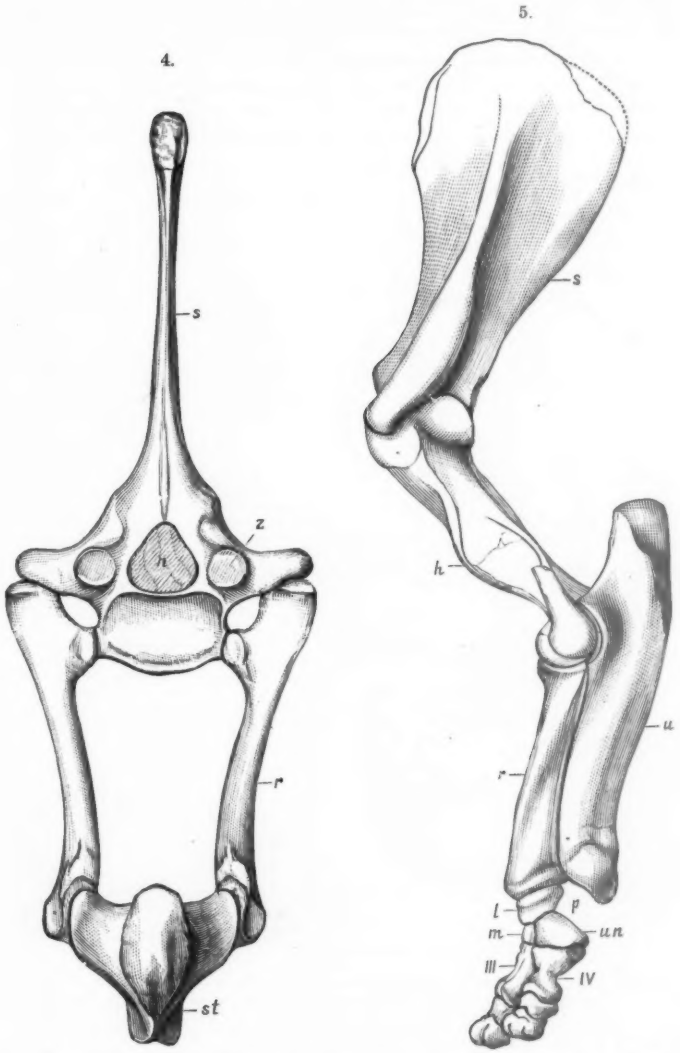


FIGURE 4.—First dorsal vertebra of *Stylinodon mirus*, with ribs and sternum in position; front view. One-half natural size.
n, neural canal; *r*, rib; *s*, spine; *st*, sternum; *z*, anterior zygapophysis.

FIGURE 5.—Left fore leg of same individual; outside view. One-fourth natural size.
h, humerus; *l*, lunar; *m*, magnum; *p*, place for pyramidal; *r*, radius; *s*, scapula; *u*, ulna; *un*, unciform; III, third metacarpal; IV, fourth metacarpal.

The inner structure of the shaft is shown in figure 7, *b*. The peculiar head of this humerus, with its strong tuberosity, the prominent deltoid ridge, and the supinator crest below, together with the supracondylar foramen and distal articulation, are all characteristic features, and taken together clearly indicate the Edentate nature of the animal to which this bone belonged.

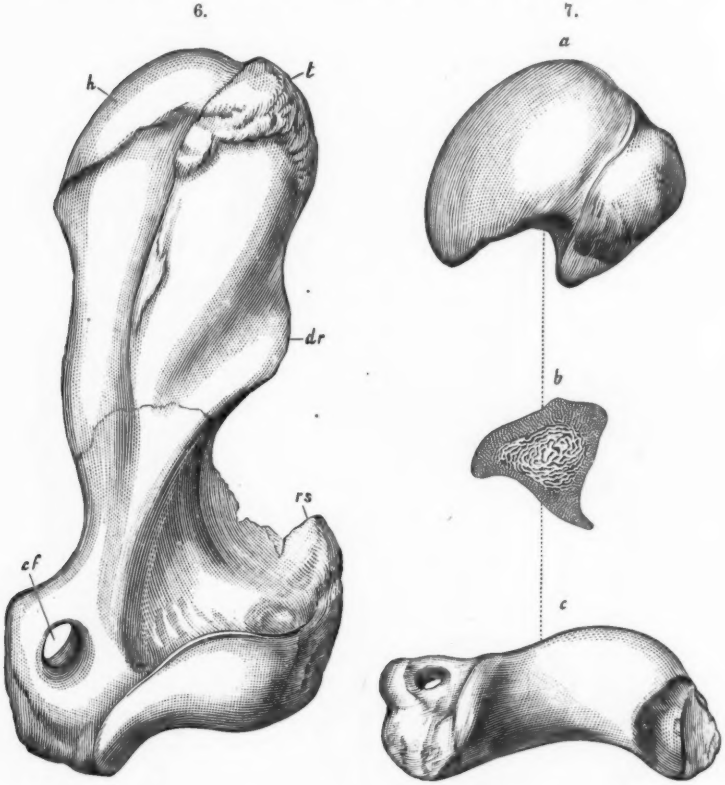


FIGURE 6.—Left humerus of *Stylinodon mirus;* front view.
cf, supracondylar foramen; *dr*, deltoid ridge; *h*, head; *t*, external tuberosity; *rs*, supinator ridge.
FIGURE 7.—Ends and section of same bone.
a, proximal end; *b*, transverse section; *c*, distal end.
All the figures are one-half natural size.

The radius and ulna are shown in position in figure 5. The radius (*r*) is much the smaller bone, and is placed nearly in front of the ulna (*u*). The latter is quite robust, and has a strong, powerful olecranon process, as shown in the figure. These bones also are Edentate in type.

The bones of the carpus and manus of this individual are only in part preserved, but those represented in figure 5 will serve to indicate the general nature of the fore foot. There were apparently five digits in this foot, although the fifth was small or rudimentary. The metacarpals were quite short, as indicated by the third and fourth. The phalanges were also short, and the median ones, at least, possessed claws.

The above description and figures of *Stylinodon* will in themselves be conclusive evidence to most anatomists that this genus has close affinities with the Edentates, if it is not a typical member of that group. Its relation to other allied genera will be discussed in a later communication.

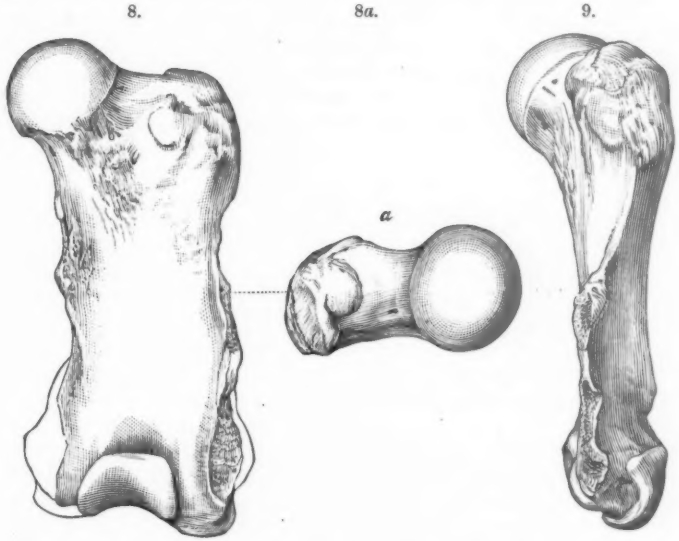


FIGURE 8.—Left femur of *Morotherium gigas*, Marsh; front view.
FIGURE 8a.—Proximal end of same bone.
FIGURE 9.—The same bone; outer view.
All the figures are one-sixth natural size.

The reference in the original description of *Stylinodon* to its resemblance with *Toxodon* is also worthy of some consideration, as the latter genus is now believed to be nearly related to various forms long considered Edentates, but at present regarded by many as aberrant Ungulates, since, notwithstanding the apparent resemblance of the feet to those of Edentates, the teeth indicate affinities with the perissodactyles.

This peculiar group, the *Chalicotheria*, of which *Chalicotherium*, Kaup, is the type genus, is now known to have its

representatives in America, Europe, and Asia. One genus, *Ancylotherium*, from the Miocene of Greece, was described by Gaudry as an Edentate. The term *Ancylopoda* derived from this genus has been recently used for the whole group, but, as the writer has already suggested, should be replaced by the name *Chalicotheria*.*

To this group, the genera *Moropus* and *Morotherium*, described by the writer as Edentates,† have been recently referred by some authors not familiar with the specimens on which these genera were based. While it is possible that the nature of some of the remains attributed to the former genus may be fairly in doubt, there can be no question that the two known species of *Morotherium* are both true Edentates. The type specimen of the latter genus is well represented in figures 8 and 9, above. It was mainly the remains of these two genera that suggested to the writer some important conclusions as to the early history of Edentate mammals, which are in part quoted below, since they seem to have been overlooked by recent writers.

Origin of the Edentates.

The affinities of the *Stylinodontia* as now determined have brought up again a most interesting question as to the origin and former geographical distribution of the Edentates, and it may not be out of place to repeat here what the writer said on this subject nearly twenty years ago, in an address before the American Association for the Advancement of Science, at the Nashville meeting, August, 1877.‡ The main passages relating to the Edentates are as follows:

"The Edentate mammals have long been a puzzle to zoölogists, and up to the present time no clew to their affinities with other groups seems to have been detected. A comparison of the peculiar Eocene mammals which I have called the *Tillodontia*, with the least specialized Edentates, brings to light many curious resemblances in the skull, teeth, skeleton, and feet. These suggest relationship, at least, and possibly we may yet find here the key to the Edentate genealogy. At present, the Tillodonts are all from the lower and middle Eocene, while *Moropus*, the oldest Edentate genus, is found in the middle Miocene, and one species in the lower Pliocene." * * *

*The term *Ancylopoda* is preoccupied, having been used by Gray, in 1848, for a group of Brachiopoda.

† This Journal, vol. vii, p. 531, May, 1874; and vol. xiv, p. 249, September, 1877.

‡ Introduction and Succession of Vertebrate Life in America. This Journal, vol. xiv, pp. 338–378, November, 1877.

"The Edentate Mammals are evidently an American type, and on this continent attained a great development in numbers and size. No Eocene Edentates have been found here, and, although their discovery in this formation has been announced, the identification proves to have been erroneous. In the Miocene of the Pacific coast, a few fossils have been discovered which belong to animals of this group, and to the genus *Moropus*. There are two species, one about as large as a tapir, and the other nearly twice that size. This genus is the type of a distinct family, the *Moropodidæ*. In the lower Pliocene above, well-preserved remains of Edentates of very large size have been found at several widely-separated localities in Idaho and California. These belong to the genus *Morotherium*, of which two species are known. East of the Rocky Mountains, in the lower Pliocene of Nebraska, a large species apparently of the genus *Moropus* has been discovered. The horizon of these later fossils corresponds nearly with beds in Europe that have been called Miocene. In the Post-Pliocene of North America, gigantic Edentates were very numerous and widely distributed, but all disappeared with the close of that period. These forms were essentially huge sloths, and the more important were *Megatherium*, *Mylodon*, and *Megalonyx*." * * *

"It is frequently asserted, and very generally believed, that the large number of huge *Edentata* which lived in North America during the Post-Pliocene were the results of an extensive migration from South America soon after the elevation of the Isthmus of Panama, near the close of the Tertiary. No conclusive proof of such migration has been offered, and the evidence, it seems to me, so far as we now have it, is directly opposed to this view. No undoubted Tertiary Edentates have yet been discovered in South America, while we have at least two species in our Miocene, and, during the deposition of our lower Pliocene, large individuals of this group were not uncommon as far north as the forty-third parallel of latitude, on both sides of the Rocky Mountains. In view of these facts, and others which I shall lay before you, it seems more natural to conclude, from our present knowledge, that the migration, which no doubt took place, was from north to south. The Edentates, finding thus in South America a congenial home, flourished greatly for a time, and, although the larger forms are now all extinct, diminutive representatives of the group still inhabit the same region." * * *

"The Edentates, in their southern migration, were probably accompanied by the horse, tapir, and rhinoceros, although no remains of the last have yet been found south of Mexico.

The mastodon, elephant, llama, deer, peccary, and other mammals, followed the same path. Why the mastodon, elephant, rhinoceros, and especially the horse, should have been selected with the huge Edentates for extinction, and the other Ungulates left, is at present a mystery, which their somewhat larger size hardly explains." * * *

"I have already given you some reasons for believing that the Edentates had their first home in North America, and migrated thence to the southern portion of the continent. This movement could not have taken place in the Miocene period, as the Isthmus of Darien was then submerged; but, near the close of the Tertiary, the elevation of this region left a much broader strip of land than now exists there, and over this the Edentates and other mammals made their way, perhaps urged on by the increasing cold of the glacial winters. The evidence to-day is strongly in favor of such a southern migration. This, however, leaves the Old World Edentates, fossil and recent, unaccounted for; but I believe the solution of this problem is essentially the same, namely, a migration from North America. The Miocene representatives of this group, which I have recently obtained in Oregon, are older than any known in Europe, and, strangely enough, are more like the latter and the existing African types than like any of our living species. If, now, we bear in mind that an elevation of only 180 feet would close Behring's Straits and give a road thirty miles wide from America to Asia, we can easily see how this migration might have taken place. That such a Tertiary bridge did exist, we have much independent testimony, and the known facts all point to extensive migrations of animals over it."

The discoveries made within the last two decades, or since the above was written, have added much to a knowledge of the subject here discussed, but have not modified materially the conclusions given in the foregoing quotations. In regard to the origin and distribution of the Edentates, present evidence tends to confirm the opinion there recorded, that this great group of peculiar mammals originated in North America, and migrated to other parts of the earth, where their remains have since been found, or their living representatives still exist.

Yale University, New Haven, Conn., January 19th, 1897.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Diffusion of Metals.*—In his Bakerian lecture Roberts-Austen has given the results of some elaborate experiments showing the tendency of two or more metals to mix spontaneously and thus to form a homogeneous mass. Already in 1883, he had observed that "while molten copper and antimony interpenetrate but slowly, the mobility of gold and silver in molten lead is comparatively rapid." In his later experiments molten lead and bismuth were selected as the fluids into which the diffusion of the other metals took place. The tubes containing this molten metal, which were about 200^{mm} long and 10^{mm} internal diameter, were arranged in an air bath with double walls, which could be readily maintained at fixed temperatures, determinable accurately by means of thermoelectric junctions. To avoid convection currents the tubes were kept hotter at top than at bottom. After a suitable time, varying from six hours to seven days, the diffusion tubes were removed, cooled, carefully measured and cut into transverse sections; the contents of each section being weighed and analyzed. Kelvin, as a deduction from Fourier's theory of heat-conduction, states the law of diffusion as follows: "The rate of augmentation of the 'quality' per unit of time is equal to the diffusivity multiplied into the rate of augmentation per unit of space of the rate of augmentation per unit of space of the 'quality.'" By "quality" is here meant the concentration of the diffused matter. Hence the law may be represented by the differential equation

$$dv/dt = k(d^2v/dx^2)$$

where x is distance in the direction of diffusion, v is the degree of concentration of the diffusing metal, t the time, and k the diffusion constant; *i.e.*, the number which expresses the quantity of the metal in grams which diffuses through unit area (one sq. cm.) in unit time (one day) when unit difference of concentration (in grams per cubic cm.) is maintained between the two sides of a layer one centimeter thick. Since the unit of diffusivity has the dimensions $[L^2T^{-1}]$ the diffusion constants may be expressed in square centimeters per day. Each pair of metals has a perfectly definite constant of diffusion at a given temperature. On tabulating the results obtained it appears that gold diffuses more rapidly in bismuth and in tin than in the heavier metal, lead, as also does platinum; the diffusion of both being about equally increased when bismuth is replaced by lead. Platinum diffuses more slowly in lead than gold does, while rhodium diffuses almost as rapidly; suggesting that the platinum metals are molecularly more complex than gold or silver.

The second part of the research was devoted to the question whether gold would still permeate lead if the temperature were maintained far below the fusing point of the latter metal. In the first experiments, thin plates of gold were fused to the lower ends of cylindrical rods of lead 14^{mm} in diameter and 70^{mm} long, and these cylinders were maintained for thirty-one days in a little iron chamber lined with asbestos and kept at 250° C, 75° below the melting point of lead. The cylinders were then measured, cut into sections and assayed. Gold was found through the entire length of the cylinder, the diffusivity being in one case 0·023 and in another $0{\cdot}03^{sq\ cm}$ per diem. At 200°, the experiment lasting only ten days, the values were 0·007 and 0·008. Since the eutectic alloy of gold and lead fuses at 200°, experiments were made to see if gold would diffuse into solid lead at 165°, a temperature below this point. The diffusivity was found to be 0·005 and $0{\cdot}004^{sq\ cm}$ per diem. Even as low as 100°, the diffusivity was found to be 0·00002. Experiments were also made on the diffusion of gold into solid silver at 800°; a temperature 160° below the fusing point of silver and 50° below that of the eutectic alloy of these metals. The results gave a diffusivity of the same order as that of gold in lead at 200°.—*Phil. Trans.*, clxxxvii, A, 383–415, 1896. G. F. B.

2. *On Optical Rotation in the Crystalline and the Liquid States.*—The specific rotation of several uniaxial crystals which polarize circularly, has been examined by Traube, in connection with the rotatory power possessed by them in the melted or dissolved states. Thus the hexagonal-trapezohedral-tetartohedral crystals of patchouli camphor have a rotation for the D line of −1·325° per mm. in the optic axial direction; while in the fused state the specific rotation $[\alpha]_D = -118°$ and in alcoholic solution $[\alpha]_D = -124{\cdot}5$. Since these values correspond to rotations of −1·240° and −1·308° per mm. respectively, it follows that this camphor has practically the same specific rotation in the crystalline and amorphous states. The same is true of ordinary camphor. Matico camphor on the other hand, although crystallizing in the same system, gives a rotation of −1·877° for the D line, in plates 1^{mm} thick; while the melted substance has the specific rotation $[\alpha]_D = -29{\cdot}17°$. Hence the rotatory power is about six times as great in the crystalline as in the melted state. Rubidium tartrate crystallizes in the hexagonal-tetartohedral system, the crystals of the dextrotartrate being lævorotatory and those of the lævotartrate being dextrorotatory. Plates 1^{mm} thick rotate 10·12° to 10·24° for the sodium line; while in aqueous solution and for a thickness of 1^{mm} the rotation is only 0·69° and of the opposite sign to that of the crystals. Cæsium dextrotartrate is isomorphous with the rubidium salt, the crystals giving a rotation of −14° to −19° per mm. for the D line; this rotation being opposite in sign to that of the aqueous solution.—*Ber. Ak. Berl.* x, 195–205, 1895; *J. Chem. Soc.*, lxx, ii, 509, September 1896.

G. F. B.

3. *On the Electrolysis of Water.*—The electromotive force required for the electrolysis of water was shown by v. Helmholtz to depend upon the density of the oxygen and the hydrogen at the electrodes, being lower in proportion as this density is smaller; so that if all gas be removed from the liquid, its value must be zero. From an equation connecting the electromotive force of polarization A, for any given pressures of the oxygen and hydrogen p_o and p_h, with the electromotive force when the pressure is the pressure of the atmosphere p_a, he has determined the value A_a to be 1·783 volts. Sokoloff has sought to obtain a direct proof that water can be decomposed with any electromotive force however small. For this purpose he used a voltameter containing two platinum plates, an insulated platinum point being placed near each plate. On passing a current, the electrodes became polarized by gas layers of definite density. Since these gases are electrically neutral and therefore free, they diffuse through the liquid, reach the platinum points, and polarize them also. By using a sensitive electrometer, the author has shown that any electromotive force, however small, can effect the electrolysis. Moreover, he finds that an electromotive force of one volt suffices to produce gas having a measureable pressure. In one experiment, which lasted 16 months, a calomel cell (1·072 volt) produced gas of 2·53^{mm} pressure; and this even seems not to be the limiting value, as the pressure continued to increase. Similar difficulties were met with here to those encountered in ordinary electrolysis. Forces are active on the surfaces of the electrodes which hinder the free diffusion of the gases and bring about the absorption of these gases by the platinum and other metals. Hence the accurate determination of A_a is not easy. Measurements at low pressures gave the author a value of 0·745 volt for A_a; a value much smaller than that given by v. Helmholtz.—*Wied. Ann.*, II, lviii, 209–248, June, 1896. G. F. B.

4. *On the Electrolytic Production of Hypochlorites and Chlorates.*—The electrolysis of solutions of potassium chloride has been investigated by Oettel. The current from four storage cells was passed through (1) a copper voltameter for measuring its strength, (2) an electrolytic gas voltameter, (3) the cells for the experiments, (4) an ampere meter, and (5) a resistance box. The electrodes of the gas voltameter were of nickel rolled into two concentric cylinders, and immersed in solution of caustic soda. The experiment cell had a capacity of about 115^{cc} and was closed tight by means of a rubber cover. Through this cover passed the wires to the electrodes, both being of platinum, a capillary delivery tube and another glass tube reaching to the bottom of the cell, by means of which it could be filled or emptied. The current strength employed was from 1 to 1·2 ampere, and it was continued for two hours. Using neutral solutions, the author finds that the main product is hypochlorite, 83 per cent of the active chlorine existing in this form at the end of the experiment, and 17 per cent as chlorate. Addition of

alkali, since it favors the decomposition of the water, increases the amount of chlorate formed. Raising the temperature acts similarly. Diminishing the density of the current at the kathode favors the reduction of the hypochlorite, the effect being greatest in a strong solution either neutral or slightly alkaline. At the anode, however, such a diminution increases the amount of water decomposed, the effect being less marked in a strongly alkaline solution. Since in an alkaline solution the reduction is a minimum, no diaphragm is necessary.—*J. Chem. Soc.*, lxx, ii, 517, September, 1896. G. F. B.

5. *On the Action of Nitrous acid in a Grove cell.*—It has been observed by IHLE that if the nitric acid in a Grove cell be gradually diluted with water, the electromotive force remains nearly constant until the acid contains 38 per cent of HNO_3. On further dilution, the electromotive force falls from 1·8 to 0·7 volt, having the lower value with 28 per cent nitric acid. If, however, potassium nitrite be added to the 28 per cent nitric acid, the electromotive force rises to 1·8 volt again, but falls to 0·7 volt when the nitrous acid present is destroyed by potassium permanganate, hydrogen peroxide, carbamide, etc. Conversely the electromotive force of an acid stronger than 38 per cent is lowered by the addition of permanganate or of carbamide. It is evident, therefore, that nitrous acid is the real depolarization agent in a Grove cell.—*J. Chem. Soc.*, lxx, ii, 554, October, 1896. (See the author's paper in *Zeitschr. physikal. Chem.*, xix, 577, May, 1896.) G. F. B.

6. *On the Spectra of Fused Salts of the Alkali Metals.*—Because of the comparative simplicity of the spectra of the alkali metals, DEGRAMONT finds the salts of these metals to offer special advantages for the study of the line spectra of the non-metals by the action of a highly condensed spark on the fused salt. The spectrum thus obtained differs considerably from that obtained with the metal itself or that given with the fused salt and a non-condensed spark. Chlorides, bromides and iodides decompose readily under these conditions; while fluorides show but little tendency to dissociate, and carbonates, though dissociated with difficulty, give the spectra of the metals in their simplest form, no lines of carbon being observed. Salts of sodium show three intense double lines 6160–6154, 5895–5889, 5867–5862, the other lines being weak, though 5675, 5669, 5155, 5152, and a broad nebulous band 4983–4978, are discernable. Salts of potassium show 7698, 7665, 6939, 6911, 6308, 6245·5, 6117·5, 5832, 5811, 5801, 5783, 5360, 5344, 5340, 5323, 5113, 5099, 4828, 4389, 4309, 4264, 4223, 4185 and 4045. Lithium salts give 6706, 6103, 4972, 4603, 4273, 4132; the small number of lines making the salts of this metal particularly well suited for studying the spectra of the non-metals. When fused phosphates are subjected to the action of the condensed spark in this way, a line spectrum of phosphorus is obtained superior to that seen in a Plücker tube. Using the potassium or sodium salt, the following lines appear: 6506 (dif-

fuse) 6458, 6088, 6042, 6034·5, 6025, 5498·5, 5462 (feeble) 5453 (feeble) 5423·5, 5409, 5385, 5340, 5311, 5292, 5250, 4968 (diffuse) 4941, 4603, 4588·5. The triplet in the red 6042–6034·5–6025, and the doublet in the blue 4603–4588·5 are the most distinctly recognized lines.—*C. R.*, cxxii, 1411, 1534, June, 1896. G. F. B.

7. *On the Preparation of Lithium and Beryllium.*—The following mode of preparing lithium and beryllium has been described by BORCHERS. In the case of lithium the solution of the chlorides of the alkalis and alkali earths is made slightly alkaline, evaporated in an iron vessel, fused with ammonium chloride to render it neutral, and electrolyzed with a current of 1,000 amperes per square meter of cathode surface, the electromotive force being 5 volts. The upper rim of the iron crucible is kept cool by a circulation of cold water, so that a thin crust of solid material is formed on the surface which prevents the metallic lithium from coming to the air. The metallic globules are placed in a paraffin bath at 130°–200° when the pure metal rises to the surface. Solutions of beryllium chloride are evaporated down with an alkali chloride and ammonium chloride and electrolyzed in the same way as magnesium chloride. Calcium and magnesium chlorides must not be present. If the temperature be not kept as low as possible, the beryllium forms an alloy with the iron of the crucible.—*J. Chem. Soc.*, lxx, ii, 520, September, 1896. G. F. B.

8. *Light of the glow beetle.*—H. MURAOKA has studied the light given by a large collection of the "Johanniskäfer" and has found some interesting relations between this light and the effects of the radiation from uranine salts observed by H. Becquerel. The chafer or beetle used by the author constitutes one of the sights of Kyoto, Japan. About the middle of June one sees thousands of these beetles lighting up the environs of the towns. The experiments were conducted with over 300 of these chafers confined over the experimental sensitive plates by means of a net. It was discovered that the natural light of the chafer resembles ordinary light; but on filtration through cardboard or through copper plates the radiations exhibit phenomena similar to those observed by Becquerel, and also phenomena analogous to the Röntgen rays. The filtered rays manifest an extraordinary phenomenon (das Saugphänomen) which is analogous to the behavior of the magnetic force lines toward iron. The peculiarities of the filtered glow-beetle rays appear to depend upon the physical character of the substance through which they are filtered—perhaps its density. The peculiar phenomena observed are obtained by filtration. In an analogous way can X-rays be obtained by filtration—and this process suggests a means of rendering such rays homogeneous. The filtered glow-beetle rays show clearly reflection. It is difficult to show refraction, interference and polarization, yet the author believes that these phenomena are present. The filtered rays of this insect appear to occupy, like the fluorescence rays of Becquerel, a mean position between the

ultra-violet rays and the Röntgen rays.—*Ann. der Physik und Chemie*, No. 12, pp. 773–781. J. T.

9. *Röntgen Rays.*.—In some recent experiments conducted in the physical laboratory of the University of Glasgow by Lord KELVIN, assisted by J. C. Beattie and M. Smoluchowski de Smolan (Nature, Dec. 31, 1896), it was shown that air drawn through an experimental tube in which it was exposed to the radiation from a Crookes tube became electrified, sometimes positively, and sometimes negatively. Professor Richard Threlfall and James A. Pollock (Phil. Mag., Dec. 1896) conclude from careful experiments that no sensible amount of matter is projected from a Crookes tube, and that the hypothesis that the action of the X-rays is due to a projection of matter is untenable. They also conclude that the phenomenon is not due to the projection of ether streams, and that no disturbance of the ether is caused which is sufficient to affect electromagnetic radiations. J. T.

10. *Electric light in Capillary tubes.*—O. SCHOTT has observed the extraordinary brilliancy of electric discharges through very fine capillary tubes. The discharges were excited by an induction coil of 25^{cm} spark length. If one makes the assumption that the duration of the spark discharge is no longer than $\frac{1}{10,000}$ of a second, a capillary of from one to two square millimeters in section radiates as much light as 1—2000 Hefner flames emit. Since the ordinary arc light has a much larger radiating surface, the capillary light is far more powerful than is created by any other source.—*Ann. der Physik and Chemie*, No. 12, p. 768–772.

J. T.

11. *Temperature of the sun.*—W. E. WILSON and P. L. GRAY have established (Phil. Trans. Acad., vol. clxxxv, 1894, p. 361), that the radiation of platinum up to the point 1600° C. obeys the law $q = a(T^4 - T_0^4)$, in which T is the absolute temperature of platinum, T_0 the absolute temperature of the surrounding medium. They have now deduced another formula, $q = b(T^3 - T_0^3) + a(T^4 - T_0^4)$, which, with suitable choice of the constants a and b, represents the radiation of polished platinum or blackened platinum. The authors find by extrapolation in their formula that the temperature of the hottest portion of the positive carbon attains a temperature of 3300° C. The radiation of the hottest portion of the positive carbon is nearly three times as great as that from the hottest portion of the negative carbon. Likening the sun to a black body, in respect to radiating power, the authors find that the temperature of the sun should be in the neighborhood of 8000° C.—*Proc. Roy. Soc., London*, vol. lviii, p. 24, 1895. J. T.

12. *Argon and helium.*—LOCKYER has examined the spectra of the gas obtained from uraninite or cleveite, bröggerite, and divers other minerals, and cites various cases in which lines are obtained in certain gases which do not appear in other gases, and concludes that argon and helium are mixtures of which the separation will be very difficult. He has also compared the wave-lengths of the lines of argon with the wave-lengths of lines

observed in the chromosphere, and in the nebula of Orion. A great number of these lines are identical, and this fact appears to throw a new light upon the numerous lines in the sun and the fixed stars the origin of which has been obscure. Argon and helium apparently establish a close connection between the elements of our planet and those of the other celestial bodies. When the intensity of the electric discharge through the gas from uraninite is augmented, carbon lines are rendered more feeble and others stronger. The author believes that this phenomenon indicates that the gas is a mixture. If one passes the discharge for a long time through helium, the yellow luminescence disappears. This results from the products of the combination of platinum which are decomposed when one afterwards heats the discharge tube.—*Proc. Roy. Soc.*, vol. lviii, 1895, p. 67, 113, 116, 192, 193.

J. T.

II. Geology and Natural History.

1. *U. S. Geological Survey.*—The seventeenth annual report of the director, C. D. Walcott, gives a full account of the operations of the survey for 1895 and 1896 (pp. 200). There were 32 geological, 6 paleontological, and a still larger number of topographic parties in the field distributed through the United States from Alaska to Florida.

Shaler continued work upon the Narragansett coal field. Emerson was engaged in mapping central Massachusetts; Dale. the adjoining portions of Vermont and New Hampshire; and Hobbs, the Cornwall district of Massachusetts. Wolff and Clark in New Jersey; Keith in Maryland; Taft, Darton and Campbell in the Virginias; and Hayes in the southern Appalachians, continued geological mapping and completed a number of sheets. Eldridge studied the phosphates of Florida, and the gilsonite of Utah; David White continued his work on the coal-bed floras and his results are proving very valuable in identifying coal horizons. Van Hise, aided by Bayley, Smyth and others continued areal work in the Lake Superior region. Gilbert was in Colorado and Kansas; R. T. Hill in Texas; Weed in Montana. Emmons, assisted by Spurr and Tower, surveyed the Aspen mining district and made a reconnaissance into Montana and Idaho; Cross mapped the Telluride district of Colorado; R. C. Hills continued the survey of the coal and iron areas of south central Colorado. Turner and Lindgren were in the gold belt of California; Branner and Lawson in the San Francisco region; Diller in northwest Oregon; and Willis in northwestern Washington. Becker and Dall studied the gold and coal of the coastal regions of Alaska. Chamberlin, assisted by Salisbury, Leverett and others, continued his glacial investigations. Stanton studied the paleontology of the Cretaceous of Texas; Ward, the paleobotany of the Cretaceous and Jurassic of California; Knowlton of the Denver basin, while

the director himself did field work in Massachusetts, North Dakota, Montana, Idaho and Washington.

Separates of four accompanying papers in the seventeenth annual report have already been issued,* "The underground waters of the Arkansas Valley in eastern Colorado" (pp. 51), by G. K. Gilbert, "Geological reconnaissance in northwestern Oregon" (pp. 80), by J. S. Diller, "The Uintaite (Gilsonite) Deposits of Utah" (pp. 41) by G. H. Eldridge, and "The Water Resources of Illinois" (pp. 147) by Frank Leverett.

Monograph XXV, "The Glacial Lake Agassiz," (pp. 658) by Warren Upham, is a culminating publication of many papers. It contains, besides numerous maps, a full account of the facts and of Mr. Upham's views concerning them, and also a brief statement (pp. 244–251) of some alternative views by Prof. Chamberlin.

Six bulletins have appeared since July†: "The Catalogue and Index of contributions to North American Geology," 1732–1891; Bulletin No. 127 (pp. 1054), by N. H. Darton; and the "Bibliography and Index of North American Geology, Paleontology, Petrology and Mineralogy" for 1892–3; Bulletin No. 130 (pp. 210), for 1884; Bulletin No. 135 (pp. 141), and for 1895, Bulletin No. 146 (pp. 130), all three by F. B. Weeks, are invaluable aids to the working geologist, and their prompt publication by the survey is especially commendable.

Florence Bascom, in Bulletin No. 136 (pp. 124), on "The Ancient Volcanic Rocks of the South Mountain, Pennsylvania," described an acid and basic series of pre-Cambrian lavas. M. E. Wadsworth and G. H. Williams have advocated the volcanic origin of similar rocks at a number of points in the Atlantic states from Maine to Georgia, but this is the first full presentation of the facts from a single region (see further, p. 160).

F. H. Newell, in Bulletin No. 140 (pp. 356), gives the report of progress in the division of hydrography for 1895, and records stream measurements in many states and territories.

A brief contribution to the geology and paleontology of northwestern Louisiana, Bulletin 142 (pp. 63), by T. Wayland Vaughan, considers the Cretaceous, Tertiary and Pleistocene of that region and describes twelve new species of mollusks.

C. D. Perrine, in Bulletin No. 147 (pp. 22), notes the earthquakes in California in 1895. About forty shocks are recorded by the seismographs of the Lick Observatory. Bulletins Nos. 68, 96, 112, 114, and 129 contain records for previous years.

The following folios have been issued:

No. 26, Pocahontas, Va., lat. 37° to 37° 30′, long. 81° to 81° 30′, by M. R. Campbell.

No. 27, Morristown, Tenn., lat. 36° to 36° 30′, long. 83° to 83° 30′, by Arthur Keith.

No. 29, Nevada City, Cal., by Waldemar Lindgren.

The maps in folio No. 26 show the distribution of twelve for-

* For notices of two of these papers, see pp. 155, 156.

† See this Journal, vol. ii, pp. 84, 303, 306, 395 and 456, 1896.

mations in the Carboniferous, nine in the Devonian and Silurian, and two in the Cambrian. Those in folio No. 27 show two in the Carboniferous, two in the Devonian, ten in the Silurian, and six in the Cambrian. Folio No. 29 contains the Grass Valley, Nevada City and Banner Hill special maps, all upon a scale of $\frac{1}{14,400}$. This important placer and quartz mining district, which is described in six folio pages of text, has already produced about 120,000,000 of dollars. The maps show Carboniferous, Jura-trias, Eocene and Pleistocene formations, besides eleven eruptives, as well as many quartz veins and auriferous gravel deposits.

J. S. D.

2. *A geological reconnaissance in Northwestern Oregon;* by J. S. DILLER. (From the Seventeenth Annual Report of the U. S. Geol. Survey. Part I.)—The author has given brief but clear accounts of the topography, the features of the coast range and of the Oregon coast, and notes of the work reported by previous authors. He describes the geological formations met with, consisting of slight traces of pre-Cretaceous rocks. He concludes that, contrary to previous opinions, "it is quite improbable that pre-Cretaceous sedimentary rocks form any considerable portion of the Coast Range in Oregon north of Coquille." Much the same statement may be made regarding the Cretaceous. "No certain Cretaceous rocks are known in the [Coast] range, and yet it is probable that they do occur where it joins the Klamath mountains. South of Roseburg a short distance along Myrtle Creek, are Cretaceous conglomerate sandstone and shales. . . . . indicated by the form of Aucella and other fossils they contain" (p. 16).

A large tract of Eocene rocks forms the great mass of the coast range from near the Columbia to the Coquille. These rocks are of both igneous and sedimentary origin.

The tufas in the former contain fossils of Eocene age. The shales generally contain marine fossils and in several places coal has been discovered in them. They are named the *Arago beds* from Cape Arago, near which the coal-bearing strata have been known for several years through the observations of Prof. Thomas Condon. The upper part of the series are sandstones and have yielded Eocene fossils as determined by Dr. Dall. Oligocene, Miocene, Pliocene and Pleistocene deposits are distinctly recognized; and the author has shown the geological history of the region as indicated by evidences of erosion, elevation and depression and the relation of the several beds to each other. Special tribute is given to the contributions made by Professor Condon to the knowledge of the geology of Oregon.

In the second part, on economic geology, account is given of the coal fields and a few other mineral products of the region.

The age of the coal is in some cases known to be that of the Eocene formation (Pebble Creek, Cape Arago, Callahans, and north Fork of the Umpqua). In other places the coal occurs in beds known to be older than some Miocene beds. At Coos Bay

the age is somewhat uncertain, but the evidence seems to point to probable Eocene rather than Miocene age. H. S. W.

3. *The underground water of the Arkansas Valley in Eastern Colorado;* by G. K. GILBERT. (From the Seventeenth Annual Report of the U. S. Geol. Survey. Part II.)—This is an excellent piece of descriptive geology, adapted to the needs of those who will reap most benefit from it, i.e., the people living in the region described.

The author has used fossils as true "*Leitfossilien*," marks of the various formations in which they occur; and among them he has included a beautiful plate of "nodules of marcasite," characteristic of the lower part of the Timpas limestone. The ordinary well driller should be able, with the use of this essay, to locate any one of the formations passed through. The Dakota sandstone is said to be the only valuable source for artesian water in the region discussed, and much care is taken to demonstrate the depth undergound and slope of this sandstone, by the aid of diagrammatic sections across the region in various directions, and by clear definitions, in simple but thoroughly scientific language.

H. S. W.

4. *The Geological Society of America.*—The ninth annual meeting of the Geological Society was held in Washington, D. C., December 29th, 30th and 31st. The following officers were elected for the ensuing year:—President, Edward Orton, Columbus, O.; 1st Vice-President, J. J. Stevenson, New York City; 2d Vice-President, B. K. Emerson, Amherst, Mass.; Secretary, H. L. Fairchild, Rochester, N. Y.; Treasurer, I. C. White, Morgantown, W. Va.; Editor, J. Stanley-Brown, Washington, D. C.; Councillors, J. S. Diller, Washington, D. C., W. B. Scott, Princeton, N. Y. The sessions were held in the Hall of the National Museum and were presided over by the President, Joseph Le Conte, Berkeley, Cal. Memorials of deceased fellows were read as follows:—of Robert Hay, by R. T. Hill: of Charles Wachsmuth, by Samuel Calvin; of N. J. Giroux, by R. W. Ells.

The following is a list of the papers presented for reading:

JOSEPH LE CONTE: The different kinds of earth-crust movements and their causes. (President's address.)

J. S. DILLER: Crater lake.

J. F. KEMP: The Leucite hills, Wyoming.

N. H. DARTON: Physiographic development of the District of Columbia region.

N. H. DARTON: Dikes in Appalachian Virginia.

FRANK LEVERETT: On the changes of drainage in the Ohio river basin.

C. WILLIAM HAYES: The solution of quartz under atmospheric conditions.

MARIUS R. CAMPBELL: Erosion at base level.

MARIUS R. CAMPBELL: The origin of certain topographic forms.

J. B. WOODWORTH: Homology of joints and artificial fractures.

ARTHUR KEITH: Notes on the structure of the Cranberry district in North Carolina

C. H. HITCHCOCK: Notes on the stratigraphy of certain homogeneous rocks.

J. B WOODWORTH: Unconformities in Martha's Vineyard and Block Island.

ROBERT BELL: Evidences of northeasterly differential rising of the land along Bell river. (Read by title.)

GEORGE E. LADD: Surface tension of water as a cause of geological phenomena.

ERASMUS HAWORTH: Cementing materials of the Tertiary sands and gravels of western Kansas.

H. W. TURNER: The work of the U. S. Geological Survey in the Sierra Nevada.

J. W. SPENCER: Geomorphy of Jamaica as evidence of changes of level. (Read by title.)

RALPH S. TARR: The Cornell glacier, Greenland.

H. L. FAIRCHILD: Shorelines of lake Warren and of a lower water level in western-central New York.

G. K. GILBERT: Old tracks of Erian drainage in western New York.

ANGELO HEILPRIN: The assumed glaciation of the Atlas mountains of Africa.

FRANK LEVERETT: The relation of an abandoned river channel in eastern Iowa to the western edge of the Illinois icelobe.

GEORGE H. BARTON: Glacial observations in the Umanak district, Greenland.

F. B. TAYLOR: The Nipissing-Mattawa river, the outlet of the Nipissing great lakes.

F. B. TAYLOR: Moraines of recession and their significance in glacial theory.

HARRY FIELDING RIED: Mechanics of glaciers—moraines and stratification.

HARRY FIELDING RIED: Variations of glaciers.

BAILEY WILLIS: Preliminary note on the Pleistocene history of Puget sound.

WARREN UPHAM: Modified drift in St. Paul, Minnesota.

I. C. RUSSELL: Note on plasticity of glacial ice. (By title)

CHARLES R. KEYES: Physical basis for general geological correlation. (By title.)

F. D. ADAMS and A. E. BARLOW: Origin and relations of the Grenville-Hasting series in the Canadian Laurentian (with observations by R. W. ELLS.)

J. F. KEMP: The pre-Cambrian topography of the eastern Adirondacks.

J. E. WOLFF and A. H. BROOKS: The age of the white limestone of Sussex county, New Jersey.

JOSEPH F. JAMES: Notes on the Potsdam and Lower Magnesian formations of Wisconsin and Minnesota.

HENRY S. WILLIAMS: On the Southern Devonian formations.

I. C. WHITE: A complete oil well record in the McDonald field between the Pittsburgh coal and the Oil Sand. (Read by title)

DAVID WHITE: The age of the lower coals of Henry County, Missouri.

HENRY B. KÜMMEL: Structure of the Newark formation of western New Jersey.

WILLIAM B. CLARK: The Upper Cretaceous formations of the northern Atlantic coastal plain.

T. W. STANTON and F. H. KNOWLTON: Notes on the stratigraphy and paleontology of the Laramie and related formations in Wyoming.

I. C. RUSSELL: Geology of northeastern Washington.

E. H. BARBOUR: A study of nature, structure, and phylogeny of Dæmonelix.

GEORGE P. MERRILL: Notes on rock-weathering.

HENRY B. KÜMMEL: New evidence on the origin of some trap sheets of New Jersey.

C. WILLARD HAYES and ALFRED H. BROOKS: The crystalline and metamorphic rocks of northwest Georgia.

ALFRED C. LANE: The grain of rocks.

G. PERRY GRIMSLEY: The origin and age of the gypsum deposits of Kansas. (Read by title.)

5. *Pre-Cambian rocks and fossils.*—In a paper read in the geological section of the British Association, Liverpool Meeting, September, 1896, by SIR W. DAWSON, an abstract of which is published in the Canadian Record of Science, July, 1896, an account of the present state of knowledge regarding the pre-Cambrian stratigraphy is given. The base of the Cambrian is

fixed at the lower limit of the Olenellus fauna. With this it is proposed to include the Protolenus horizon of Matthew, which terminates below in a barren sandstone in both southern New Brunswick and Newfoundland.

Beneath this Cambrian system lies the *Etcheminian* system of Matthew, composed of red and greenish slates and a basal conglomerate, and containing no trilobites but fossils referred to Ostracods, Mollusks, Worms, Brachiopods, Cystideans, and Protozoa. The following formations are recognized as belonging to the Echeminian system: viz. the Signal Hill series and Random Sound series of Newfoundland, the Keweenian or Keweenawan series of Lake Superior, and the Chuar and Grand Canyon formations of Arizona. The author regards Algonkian as a term "unhappy in form and cause, and perhaps should be dropped." The Echeminian is regarded as the earliest system of Paleozoic time.

Below the Paleozoic rocks are two systems of the Eozoic. The upper member, the *Huronian* system, is separated above and below by unconformities from the contiguous rocks. "Laminated bodies comparable with Eozoan, burrows of worms, spicules of sponges and indeterminate fragments referable to Algæ or to Zoophytes," are reported from the rocks of this system. Rocks of the system are recognized in New Brunswick, Newfoundland, Lake Superior and Lake Huron, and also apparently in Colorado. The lower member of the Eozoic is named the *Grenvillian* system (the upper part of Logan's Lower Laurentian). The rocks of this system are found in the St. Lawrence and Ottawa valleys, in New Brunswick, the Adirondacks and eastern slope of the Appalachians. Among the rocks are found belts of limestone "associated with what seem to be altered sedimentary beds, and in places rich in graphite and in apatite." The fossils recognized in this system are said to be "Protozoan alone, represented by peculiar and gigantic forms, as Eozoan and Archæozoan, and some smaller types (Archæospherinæ)." H. S. W.

6. *Antiquity of man in Britain.*—The number of *Natural Science* for January, 1897, contains a note of recent discoveries by Mr. W. J. Lewis Abbott of what are believed to be evidences of the existence of man in Britain at a much earlier period than that which has been previously assigned. The specimens in question are a series of flints which at least bear a striking resemblance to the work of man, and which were obtained from the Cromer Forest Bed at Runton. They were found there sticking in the iron pan. This Forest Bed is now usually regarded as forming the top of the Pliocene series, and contains forms of the cave-bear, rhinoceros, elephant, deer, and other mammals living and extinct. A detailed account of the specimens is promised for the February number.

7. *On the Age of the Lower Coals of Missouri;* by David White. (Abstract of a paper read before the Geological Society of America, Dec. 31, 1896.)—As the result of the study of the

composition, vertical range, and geographical distribution of the plants from the lower coals of Henry County, Mo. (*The Age of the Lower Coals of Henry County, Missouri*), David White concludes that the two approximate low coals, which occasionally rest on the eroded surface of the Mississippian series in that region, are slightly younger than the Brookville, Clarion, or Mazon Creek horizons of the northern bituminous fields, though they are perhaps not so young as the middle Kittaning coal. Thus the period of the erosion of the Missisippian appears to include the time represented by the lower portion of the Lower Coal measures and the Pottsville series, a succession of sediments attaining a thickness of twelve hundred feet in the anthracite regions, or over twenty-five hundred feet in the Virginian portion of the Appalachian trough. The plants from Missouri are found by Mr. White to be probably nearly contemporaneous with those of the D ("Marcy") vein of the northern anthracite fields, but are possibly slightly younger. Forty-two of the forty-three plant genera and nearly one-half of the species occurring in this county are also present in the European basins. A critical comparative examination of the American and of the European floras leads the author, who regards the species as generally synchronous and indicating continental conditions involving greater facilities for inter-migration than geologists generally admit, to consider the Henry County coals as partially contemporaneous with the Transition Series between the Upper and the Middle Coal Measures of Great Britain, and the Third or Upper Zone of the Valenciennes series in the Franco-Belgian basin, or as referable to the Geislautern beds near the top of the Westphalian (*Saarbrücker Schichten*) of the Rhenish district.

8. *The relation of the fauna of the Ithaca group to the faunas of the Portage and Chemung;* by EDWARD M. KINDLE. Bull. Am. Paleontology, vol. 2, No. 6; pp. 1–56, with two plates. Dec. 1896.—This is an admirable example of what can be done by an exhaustive study of the fossil faunas of a single restricted area. The author has taken as his thesis the determination of the disputed question whether the fauna of the Ithaca group should be ranked with the Portage or Chemung. He has given a concise review of previous discussions over the general and particular points involved.

He has collected the fossils from over 80 different stations in the locality representing the faunas under discussion, and has identified all the species, compared the fossils, tabulated their range upward and downward in the general section, thus strongly supporting by a compact scientific argument his conclusion that "the Ithaca fauna should be classed in the Portage epoch."

H. S. W.

9. *The Phosphate-Deposits of Arkansas;* by JOHN C. BRANNER. (Read before the Am. Inst. Min. Eng. at Colorado meeting, Sept. 1896.)—The author, late State Geologist of Arkansas, has presented in this paper a concise statement of the present

known facts regarding the phosphate deposits in Arkansas. They appear to be restricted in this region to the interval between Lower Paleozoic rocks and the Carboniferous, occupied also in part by the black shale, which has been considered to be of Devonian age. The author concludes that "we are reduced to the necessity of believing that this interval, with its phosphate-deposits, represents the slow accumulation of organic matter over a comparatively deep sea (not abysmal, however) during the upper Silurian and Devonian periods."

Mr. C. W. Hayes has already discussed the similar phosphate deposits occurring in the same interval in the central Tennessee rocks.*

It may be observed that the presence of rolled and rounded pieces of fish bones, fragments of osseous plates that were ½ to ¾ in. thick, which occur among these phosphate nodules both in Arkansas and in Eastern Kentucky, as known to the writer of this note, fix the age of the deposit as not earlier than the Devonian era.

H. S. W.

10. *Die Leitfossilien, ein Handbuch für den Unterricht und für das Bestimmen von Versteinerungen;* von ERNEST KOKEN, pp. 1–848, with nearly 900 figures. Leipzig, 1896 (Tauchnitz).—This elaborate treatise must prove of great value to students of paleontology in Germany in facilitating the determination of fossils in the laboratory. But the fact that the characteristic fossils are European species, and from European faunas will prevent American students from getting from it the help they might otherwise gain. Still, the analyses made of the characters presented by the fossils of each grand division of invertebrates discussed and the orderly listing and description of the characteristics of the fossil faunas of Europe, will render the work of value in the American laboratory of paleontology whenever comparative geology is studied.

The volume is composed of two parts: the first "Paläontologische Uebersicht," gives general descriptions of the characters of fossils of the chief invertebrate types, followed by analytical tables of families and genera. The second part is "Die Leitfossilien," in which the genera are given under each class for each era, and the characteristic species of each genus selected are distinguished from each other by analytical descriptions and tables, thus bringing out with great distinctness the prominent observed features of the characteristic fossils of each horizon. H. S. W.

11. *Ueber die neue geologische Uebersichtskarte der Schweiz.* 1: 500,000; von C. SCHMIDT. Extract from Compte-rendus in Congrès géologique international 6th Session, 1894, Zurich, pp. 352–360).—This brief report gives detailed account of the classification adopted for the series of deposits from the Alluvium to the Devonian and of the crystalline rocks.

12. *The ancient volcanic rocks of South Mt., Penn.;* by FLORENCE BASCOM. U. S. Geol. Surv., Bull. No. 136, Washington, 1896.

* 16th Ann. Rep. U. S. Geol. Surv., Part IV, pp. 620–623.

8°, 124 pp., 28 pl.—The perception of the importance of the fact that considerable areas of previously unrecognized ancient rhyolitic lavas occur along the Atlantic coast and in the Appalachian region is due to the late PROF. G. H. WILLIAMS, and to his keenness and enthusiasm we owe primarily the appearance of this memoir, and the one noticed in the following section. In the present work MISS BASCOM has selected a small and typical area and has studied it thoroughly in the field and the material collected with equal thoroughness in the laboratory. Especially in the study of the characteristic structures of these ancient acid lavas, the ways in which they have been altered and modified and the means and criteria by which they may be recognized, is the work a valuable one, which must serve as a model for investigators of such rocks. It is illustrated with a large number of excellent plates which add greatly to its value. It is impossible, in the brief limits of this notice, to do more than to call the attention of the petrographer (and geologist as well) to its importance. L. V. P.

13. *The geology of the Fox Islands, Maine;* by GEO. OTIS SMITH. (Inaug. Diss. Johns Hopkins Univ., 1896.)—What has been said in the foregoing applies well to this, which is chiefly a study of a series of ancient lavas occurring off the coast of Maine. The geology of the islands has been mapped and the occurrence of a small, interesting area of the Niagara is described, in which 80 species of fossils have been found by Prof. Beecher. A variety of interesting acid volcanics have been carefully studied and the results given. The work contains one plate and an excellent map on a scale of a mile to the inch. L. V. P.

14. *The Cell in Development and Inheritance;* by EDMUND B. WILSON, pp. 1–371. New York and London, 1896. (The Macmillan Co.)—The author has presented in brief compass and in a clear and lucid manner the principal facts of our present knowledge of the cell; its morphology, chemistry, physiology and development. Without entering into so full an exposition of the theory of the cell as is given by Hertwig, the chief points in its history are given. No endeavor is made to give an exhaustive account of the cell, but rather the attempt is made to consider, within moderate limits, those features of the cell that seem more important and suggestive to the student of development. The omissions are particularly noticeable on the botanical side of the subject. The book is fully illustrated by some original figures, and by a large number of reproductions of the classic figures which have been produced by the many workers in this branch of biology. Each chapter is provided with an ample list of the literature in which the subjects discussed are elaborated.

In the last chapter the chief theories of inheritance and development are defined and discussed.

In reply to the question, "What is the nature of the germplasm and how has it been acquired?" Prof. Wilson takes an agnostic position. He says, "The truth is that an explanation of

development is at present beyond our reach," and again: "But when all these admissions are made, and when the conserving action of natural selection is in the fullest degree recognized, we cannot close our eyes to two facts: first, that we are utterly ignorant of the manner in which the ideoplasm of the germ-cell can so respond to the play of physical forces upon it as to call forth an adaptive variation; and second, that the study of the cell has on the whole seemed to widen rather than to narrow the enormous gap that separates even the lowest forms of life from the inorganic world" (p. 330). H. S. W.

15. *Tables for the Determination of Minerals by Physical Properties, ascertainable with the aid of a few Field Instruments.* Based on the System of Prof. Dr. Albin Weisbach, by PERSIFOR FRAZER, 163 pp. 1897 (J. P. Lippincott Co.).—The fourth edition of the Weisbach tables prepared by Prof. Frazer has recently been issued. A large amount of new material has been added and the tables have been adapted in other respects so as to make them even more useful than before to the student. These tables are now too well and favorably known to need more than this brief notice.

16. *Der Lichtsinn augenloser Tiere von* WILIBALD A. NAGEL. 8vo. 120 pp. Jena, 1896 (Gustav Fischer).—This memoir discusses at length the function of sight in eyeless animals. It begins with a lecture on the apparent paradox of "seeing without eyes." This is followed by an account of the author's interesting experiments showing that many animals are still sensitive to light and distinguish the direction from which it comes after the removal of the eyes. The concluding part discusses the theories of vision and perception of light in the lower animals.

17. *Additional information concerning the giant Cephalopod of Florida;* by A. E. VERRILL.—After the publication of the notice in the January number of this Journal, I received additional facts concerning this huge creature from Dr. Webb. He has also sent me photographs,* taken two days after it came ashore, giving four different views of it.

These photographs show that it is an eight-armed cephalopod, and probably a true *Octopus*, of colossal size. Its body is pear-shaped, largest near the broadly rounded posterior end. The head is scarcely recognizable, owing to mutilation and decay. Dr. Webb writes that a few days after the photographs were taken (Dec. 7th), excavations were made in the sand and the stump of an arm was found, still attached, 36 feet long and 10 inches in diameter where it was broken off distally.

This probably represents less than half of their original length, as the arms of *Octopus* generally taper very gradually and are often five or six times longer than the body. What looks like the remains of the stumps of arms is shown in the front view.†

* These were taken by Mr. Edgar Van Horn and Mr. Ernest Howatt, to whom my thanks are due for the proofs.

† I have had drawings made from the photographs of the front view and side-

The length, given as 18 feet, includes the mutilated head region. The photographs show that the "breadth," given in the first account as 10 feet, applies to the more or less divergent stumps of the arms (?) and the body taken together, as they lie on the sand. The body, itself, is almost 7 feet wide, and rises at its thickest part 3½ feet above the sand in which it is partially imbedded. The body is not greatly flattened and probably had a diameter of at least 5 feet when living. The parts cast ashore probably weighed at least 6 or 7 tons, and this is doubtless less than half of its total mass when living.

This species is probably one of those upon which the sperm whale feeds regularly on the whaling grounds off our southern coast.

Whalers have told me, years ago, that sperm whales killed in that region often vomit great masses of cephalopod flesh, including sections of huge arms. One reliable whaling captain used to say that he had seen very large suckers "as large as a dinner plate" on such fragments of arms. The suckers of this Florida *Octopus* would have been as large as that, if they had the proportions to the arms and body usual in small species of *Octopus*.

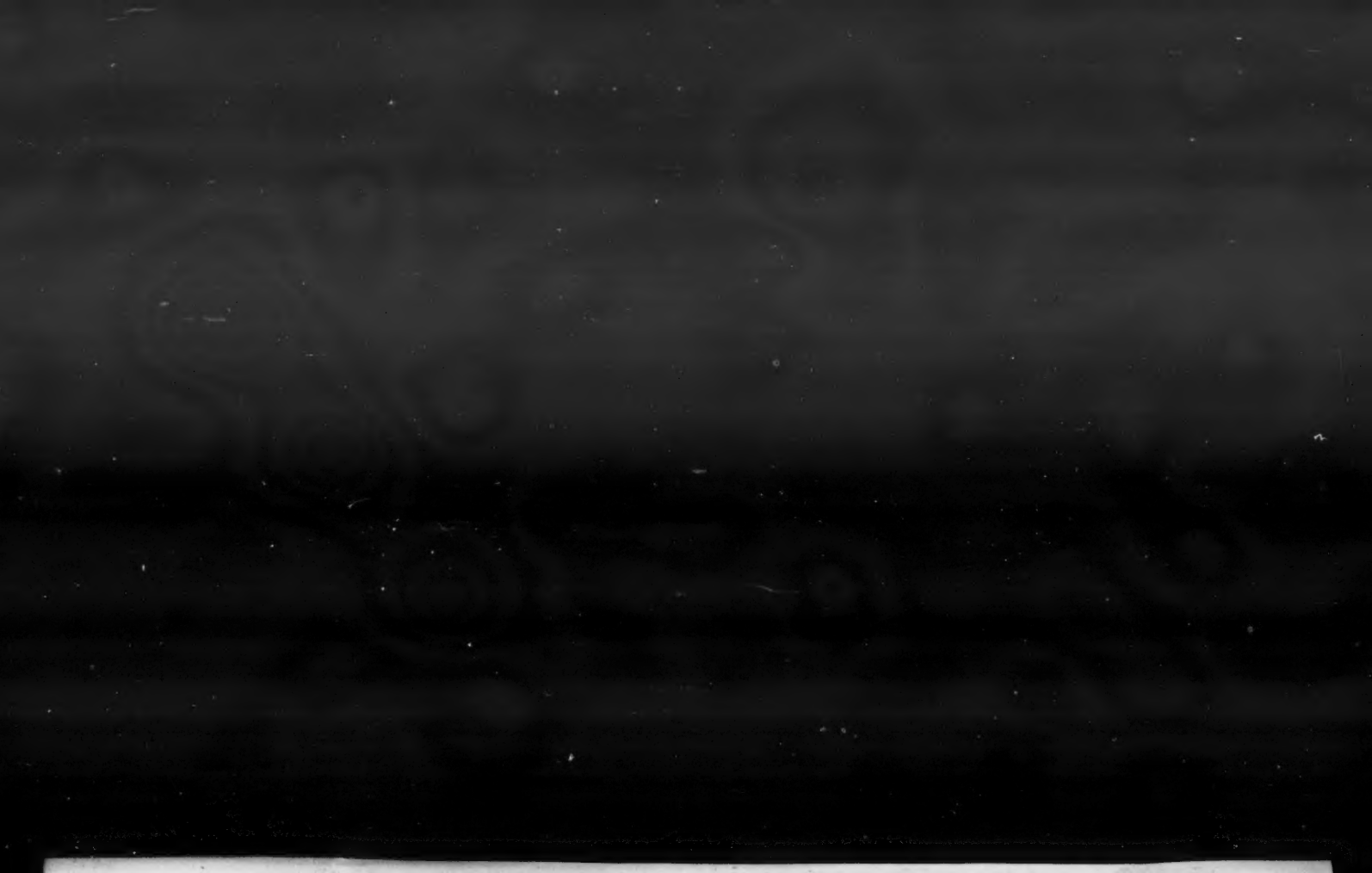
This species is evidently distinct from all known forms, and I therefore propose to name it *Octopus giganteus*. It is possible that it may be related to *Cirroteuthis*, and in that case the two posterior stumps, looking like arms, may be the remains of the lateral fins, for they seem to be too far back for the arms, unless pulled out of position. On the other hand, they seem to be too far forward for fins. So that they are probably arms twisted out of their true position. This is, at any rate, the first gigantic Octopod that has been described or figured from actual specimens.

Note. Since the above was in type, I have learned that Dr. Webb had caused the sand around the monster to be removed, and by means of six horses and powerful tackle he has moved it higher up the beach. He says that the true length of the body is 21 feet. The head is mostly or entirely gone. The outer integument has dried to a firm mass several inches thick.

view, which will be published in the American Naturalist. The photographs themselves are not strong enough for reproduction, having been over-exposed.

A notice of this *Octopus*, written by me, was published in the New York Herald, Jan. 3d, but my signature was omitted without my consent. A figure, furnished and described by me as a restoration, was inserted without any explanation: it is needless to say that it does not closely resemble the mutilated remains.

Obituary.

General Francis A. Walker, President of the Massachusetts Institute of Technology, and for 9 years (from 1872 to 1881) Professor of Political Economy and History in the Sheffield Scientific School, died suddenly in Boston on the 5th of January at the age of fifty-six. So large a part of his active and varied life was devoted to the public service, and the leading facts of his career have been given so fully in other publications, that no detailed account of his life will be expected in this Journal. But as he was the first economist to be elected to the National Academy of Sciences, the first President of the American Economic Association, and the author of numerous widely-read and important books on economic subjects, some reference must be made to the scientific side of his career.

His economic work lay in three distinct lines. He was at once the leader of an economic movement, a theoretical economist, and a statistician. His name is chiefly associated in the popular mind with the movement for the establishment of international bimetallism by an agreement among the leading states. His attitude on this subject has frequently been misunderstood. He had no sympathy with the national bimetallic movement of the campaign of 1896 which aimed at the introduction of the free coinage of silver by the United States alone, but he followed in his views very closely those of Cernuschi and other European economists. As a theoretician his most important contributions to the science are his Law of Wages and his Law of Profits. The former was first suggested in his treatise on Wages, published in 1876, and more fully developed in his text book of Political Economy published in 1882. This theory stood in direct opposition to the wage-fund theory of an earlier period, and has had an important influence upon economic thought. His theory of profits established a close parallel between profits and rent, and held that, just as rent is the remuneration for special advantages in the way of land, so profits are remuneration for special advantages in the way of business ability. As a statistician Gen. Walker's most important work lay in the management of the ninth and tenth censuses, which he developed from a mere enumeration of the population into a great statistical investigation, reinforced by numerous special studies of the principal resources of the United States. He combined in a rare degree the logical mind of the scholar, the vivid style of the popular writer, and the organizing power of the administrator. His literary activity lay in many fields, and many departments of economic science will feel his loss. H. W. F.